

# Learning and Becoming in Practice

THE INTERNATIONAL CONFERENCE OF THE LEARNING SCIENCES (ICLS) 2014

PROCEEDINGS VOLUME 3



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# **Learning and Becoming in Practice:**

## The International Conference of the Learning Sciences (ICLS) 2014

**Volume 3**

**11<sup>th</sup> International Conference  
of the Learning Sciences**

**June 23-27, 2014, Colorado, USA  
The University of Colorado Boulder**

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*Learning and Becoming in Practice: The International Conference of the Learning Sciences (ICLS) 2014*  
June 23–27, 2014  
Boulder, Colorado, USA.

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ISBN 978-0-9903550-5-2 (Volume 3, PDF Version)  
ISSN: 1814-9316

Cite as: Polman, J. L., Kyza, E. A., O'Neill, D. K., Tabak, I., Penuel, W. R., Jurow, A. S., O'Connor, K., Lee, T., and D'Amico, L. (Eds.). (2014). *Learning and becoming in practice: The International Conference of the Learning Sciences (ICLS) 2014, Volume 3*. Boulder, CO: International Society of the Learning Sciences.

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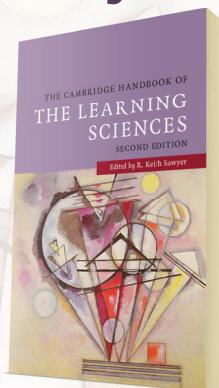
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## Preface

The international and interdisciplinary field of the Learning Sciences brings together researchers from the fields of cognitive science, educational research, psychology, computer science, artificial intelligence, information sciences, anthropology, sociology, neurosciences, and other fields to study learning in a wide variety of formal and informal contexts (see [www.isls.org](http://www.isls.org)). This field emerged in the late 1980s and early 1990s, with the first International Conference of the Learning Sciences (ICLS) held in 1991 at Northwestern University in Evanston, Illinois, USA. Subsequent meetings of ICLS were held again in Evanston, USA (1996), Atlanta, GA, USA (1998), Ann Arbor, MI, USA (2000), Seattle, WA, USA (2002), Santa Monica, CA, USA (2004), Bloomington, IN, USA (2006), Utrecht, the Netherlands (2008), Chicago, IL, USA (2010), and Sydney, NSW, Australia (2012). The 11<sup>th</sup> ICLS meeting in 2014 was hosted at the University of Colorado Boulder, USA.

Papers for this conference were submitted in November 2013, and then went through a process of peer review. We received a record number of submissions (749), 50% more than for any past ICLS conference. Overall, 306 submissions were accepted, which is an 18% increase from previous conferences. The overall acceptance rate for submissions was 41%.

Acceptance rates for each category were:

- 32% for full papers
- 38% for reports/reflections
- 52% for posters
- 55% for symposia

The program reflects broad geographic representation, with contributions from 21 countries on 5 continents.

We are especially grateful to those who performed reviews. A total of 610 people completed over 2,300 reviews of the submissions. As in recent years, for each symposium and full paper, we assigned a senior reviewer who examined all reviews and made a recommendation regarding acceptance in the category submitted, acceptance in another category, or rejection. These senior reviewers greatly helped us make decisions on acceptance for each submission.

The theme of ICLS 2014 is “Learning and Becoming in Practice.” By focusing on learning and *becoming*, we aimed to foreground the ways that learning entails becoming a certain kind of person. By focusing on learning and becoming *in practice*, we aimed to foreground the ways that learning processes are situated within different kinds of practices. We identified three kinds of practices that capture the range of contexts and processes in which people can learn: by engaging in the epistemic practices of disciplines, by participating in sociocultural practices, and by engaging in design. Two additional practices we highlight pertain to how we organize our own work as learning scientists: the practices for analyzing and modeling learning across settings and time, and the practices for designing for scale and sustainability.

In many ways, practice is a natural focus for our field. The call for conducting design research grew in part from a perception that findings generated in laboratory studies of cognition answered only a subset of the questions we had about learning. Design researchers take a deeply pragmatic stance toward research on learning, seeking to generate insights from studying learning in specific contexts. People who collaborated within key institutions in the

history of the learning sciences—such as the Institute for Research on Learning and Xerox PARC—were key to developing the rich and generative theoretical accounts of learning in practice.

The different strands related to the theme of "learning and becoming in practice" highlight several lines of inquiry in the learning sciences that address five key questions, which we elaborate below.

### **How Do People Learn Core Disciplinary Ideas by Engaging in Epistemic Practices of Disciplines?**

By disciplines, we include not only the learning in K-12 school science and mathematics, which makes up the majority of learning sciences research, but also learning in higher education and in other disciplines, including engineering, social sciences, and the humanities. The term epistemic practices refers to how different disciplines argue that people come to know and warrant their ideas; the study of learning in epistemic practices encompasses how people come to be able to participate in these practices. Scholars often speak of the epistemic "commitments" that define the boundaries of particular disciplinary communities, and this idea of commitments signals how people must come to understand and appropriate particular norms for thinking, speaking, and reasoning to be part of that community. Contemporary learning sciences research on epistemic practices is wide-ranging and includes studies of how children's understandings of the practices of modeling in science develop over time, as well as studies of classroom discourse practices and teachers' orchestration of them. Research has also highlighted how young people navigate between everyday and disciplinary forms of knowing in ways that shape their identities. Learning sciences research has also explored how such epistemic practices as explanation develop within family conversations and museums, as well as how the everyday epistemologies of learners from nondominant groups relate to epistemic practices of the disciplines.

### **How Do People Learn through Participation in Sociocultural Practices?**

The landmark volume, *How People Learn*, synthesized decades of research on learning and has greatly informed how educators design learning environments. Several of the committee members who were involved in that effort have since called for a second volume, focused on the idea of "how people learn culturally." In emphasizing culture, they draw attention to something that the report included but was not in the foreground, namely that learning is a deeply social and cultural process. Studies of learning within sociocultural practices often draw on Vygotskian and neo-Vygotskian theories of learning and development, but not exclusively so. Studies of cultural cognition in psychology and anthropology have made and continue to provide important insights into learning, as do experimental studies of social and cultural aspects of learning. Our purpose in posing this question as a central strand for our conference theme was to encourage dialogue and attention to this methodologically and theoretically diverse body of work in the field.

### **How and What Do People Learn by Engaging in Practices of Design?**

Our field has a rich tradition of research, especially within science and engineering studies, of design as a way to learn. By participating in design, learners engage deeply with disciplinary and related content; when they do it with others, they also gain practice in the valued skills of collaboration and teamwork. In the past decade, within and along the periphery of the learning sciences, the scope of what learners design has expanded. Many projects are

exploring what youth learn, for example, when they engage in complex activities of media production or contribute to social media. Still others are engaged in innovative 3D and technology-based physical construction.

An ongoing conversation within the field focuses on design-based research as a methodology. By no means settled is the debate over what it means to warrant claims about what we learn from engaging in this form of research. Other methodologies, too, play a central role in our field—from critical ethnographies to in-depth analyses of classroom discourse—that do not involve design per se. Yet these same methodologies also have promise to help us understand more about what we learn from engaging in design and how we come to know it, especially when applied to the study of our practices of design-based research.

### **What Practices Should We Use to Model and Analyze Learning across Time and Across Settings?**

A number of us in the community are engaged in innovative efforts to model and analyze learning over time and across settings. Our foci and approaches vary widely. We have conducted micro-analyses of learning using fine-grained knowledge analysis approaches, conducted longer-term developmental analyses, and mapped learning progressions within disciplines. Some in the fields of data mining and learning analytics are engaged in efforts to construct models from large data sets of learning pathways through specific content, especially in online learning environments. Still others are engaged in ethnographic studies of learning across settings and time. Some of these researchers are specifically focused on the roles of space and place within learning. Investigators across these different lines of research employ very different assumptions about the nature of learning, which makes the opportunity ripe for dialogue about the assumptions underlying the different approaches.

### **How Can We Transform Our Practice to Design More Effectively for Scaling and Sustainability?**

Many learning scientists aim to have broad impact on the fields of practice that we study, whether those are schools, museums, or another setting for learning. At the same time, we recognize that limited funding and poor infrastructure hamper our efforts to achieve such an impact. We also know that by selecting environments that are more “felicitous” for design, such as well-resourced school districts, we can unwittingly exacerbate problems associated with equity of access to powerful learning opportunities. Hence, we want to engage the community in a dialogue about how we might design more effectively for scaling and sustainability, which will provide an opportunity to highlight a wide range of efforts within the field, from rapid prototyping of online environments to emerging efforts to undertake design research at the district level, not just within classrooms or individual out-of-school settings. A key theme of many of the contributions to the conference is the importance of engaging practitioners at different levels of educational systems in design, as a means to promote more transformational and sustainable changes within systems. This dialogue allows us to pursue questions, too, of how we might need to engage in efforts to re-organize systems of learning to promote more equitable learning outcomes for all.

In these proceedings volumes, you will find a wide variety of approaches to the above questions, and we look forward to continuing the conversations these papers and sessions initiated at the conference.

Finally, we express our deepest gratitude to the many people who made the conference possible: the organizing committee, advisory committee, program committee, reviewers, sponsors, volunteers, staff, and all conference presenters and participants. Your contributions make the learning sciences a thriving field, striving to transform learning opportunities that enable people to become agents of change in their own and others' lives.

- Program Chairs Joseph L. Polman, Eleni A. Kyza, D. Kevin O'Neill, and Iris Tabak  
Conference Chairs William R. Penuel, A. Susan Jurow, and Kevin O'Connor



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# **Symposia**



# Combining Generation and Expository Instruction to Prepare Students to Transfer Big Ideas Across School Topics

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**Abstract:** Approaches combining generation and expository instruction have been shown to be beneficial for transfer. This symposium focuses on the approaches of inventing and productive failure. Both approaches delay expository instruction. Students are asked to work on a generation activity with a problem or with contrasting cases. This activity is aimed to foster transfer of the knowledge gained during subsequent expository instruction. The goal of the symposium is to contribute to a better understanding of how the generation activity is best designed to foster transfer. The contributions of this symposium varied the amount and type of generating by varying the materials (e.g., content of cases), the task (e.g., inventing vs. self-explaining), or the setting (collaborative vs. individual) of the generation activity. Mediating processes are also addressed. The symposium will clarify moderating conditions and mediating processes of how generation activities combined with expository instruction deploy their full potential.

## Overall Focus and Major Issues of the Symposium

Generative learning activities as well as expository instruction have their unique advantages for learning (Lee & Anderson 2013). Attempts to combine the two have been shown to be beneficial for transfer (Kapur, 2012; Schwartz & Martin, 2004). Transfer of big ideas across school topics is a much wanted outcome of instruction, but hard to achieve (Barnett & Ceci, 2002). The big ideas studied in the different contributions to this symposium comprise linear functions (Schalk et al.), ratios in science and mathematics (Glogger et al., Hallinen et al.), and fraction expansion (Mazziotti et al.) - all of which have great significance for various school subjects. In this symposium we focus on two forms of combining generation and expository instruction to foster transfer: First, *inventing* asks learners to generate a principle or method that allows evaluating several cases from the learning domain. ‘Cases’ in the present studies refer to examples of a domain such as the diagram of a linear function with a positive gradient, or buses with densely packed passengers as cases of a type of density. The cases usually vary critical features of the domain so that contrasting the cases helps to identify and understand the critical features. The inventing with contrasting cases activity is used as preparation for future learning from expository instruction. Second, in the approach of productive failure, the generative phase includes a complex problem. Learners usually fail to solve this problem in a canonical way. However, the combination with subsequent expository instruction is theorized to make the failure productive (Kapur, 2012). The expository instruction encompasses contrasting of suboptimal (students’) and canonical solution methods.

The benefit in transfer of these activities could be based on the deep processing of good examples (or solution methods) in an early stage of skill acquisition (Lee & Anderson, 2013). The deep processing could result in a richly elaborated mental representation of the examples. At the same time, the understanding of a deep structure, an abstract principle that “interconnects” the examples (and can be abstracted by contrasting and comparing), can be the basis for transfer (Barnett & Ceci, 2002). Contrasting cases were shown to help recognizing deep similarities between cases and abstracting generalizable principles (e.g., Alfieri, Nokes, & Schunn, 2013). The deep processing and abstracting of principles prepares to learn from the subsequent expository instruction and to transfer “big ideas” across topics. The contributions to this symposium focus on ways how to best foster deep processing and abstracting deep structures. They analyze primarily experimental variation of the generation phase.

Major issues of this set of studies refer to the questions of what conditions moderate and what processes mediate the effectiveness of different combinations of generation and expository instruction.

Moderating conditions can be the type and amount of generation. The type and amount of generation can vary depending on the task, the materials, and the setting. Regarding the task, the level of generation is highest in an inventing or productive failure task (all contributions encompass such a condition). For example, an index to evaluate the density in buses has to be invented. A somewhat lower amount of generation is required when students self-explain already evaluated cases (Schalk et al.). They still have to think towards the abstract principle that forms the basis for the evaluation of the presented cases. The next lower level of generation is to self-explain a completely worked example of the inventing problem (index and resulting evaluation of cases are provided, Glogger et al.). The type and amount of generation can also vary with the specifics of the material, here the characteristics of the cases. Characteristics of the cases that were varied in the studies of this symposium include the concreteness of the cases (idealized, abstract vs. concrete cases in Schalk et al.) and contents of the cases (isolate the main effects of key variables or include main effect and interaction of variables in Hallinen et al.). Finally, the kind of generation can vary depending on the setting such as collaborative or individual work, addressed in the study of Mazziotti et al.

Mediating processes can explain how the generation phase affects processing of the subsequent expository instruction and, in the end, how transfer is fostered. Processes discussed in this symposium are motivational such as self-efficacy and cognitive such as cognitive load (Glogger et al.).

The potential significance of each contribution is summarized in the following: Schalk, Barth, and Schumacher could show that the kind of material and the kind of task interact when students learn about linear functions: Specifically, their results suggest that self-explanation prompts should be combined with concrete cases, while invention prompts should be combined with idealized cases. They did not find differences between the generative preparatory conditions and a tell-and-practice condition.

Glogger, Gaus, and Renkl found that a higher level of generation (inventing) led to deeper encoding of the deep structure of physics ratios such as density than a lower level of generation (worked examples). Deep encoding mediated transfer. A comparison with a previous study suggests that students react differently to the task of inventing or explaining worked examples, respectively, depending on their experience with generative group activities.

Mazziotti, Loibl, and Rummel could show that productive failure in mathematics (fraction expansion) is also beneficial for a new age group, namely, elementary school children. Additionally, they varied if students worked on the preparation problem in groups or individually. A simple comparison did not reveal differences in learning outcomes depending on the social setting. However, further analyses of video data will provide more differentiated information about effective processes during collaborative generative activities.

Hallinen, Chin, Blair, and Schwartz summarize several studies on the use of contrasting cases in combining generation and expository instruction, about task orientation, and about the content of materials. They could show that more complex material (including main effects and interaction of key variables instead of just the main effects of variables) enhances future problem solving. Consistent with the symposium as a whole, they conclude that the well-chosen combination of well-designed materials and an explicit focus on generation (such as an invention task) are two key aspects to transfer big ideas across school topics.

The symposium will give the audience a chance to generate and invent hypotheses about key ideas in the symposium by providing some materials from the studies. The interactivity of the symposium will further be facilitated by discussion questions posed by the presenters.

## **Understanding the Gradient of Linear Functions: Comparing Students' Transfer Performance Resulting from Different Preparatory Constructive Learning Activities and Tell-and-Practice Instruction**

Lennart Schalk, Armin Barth, Ralph Schumacher

### **Introduction**

A major challenge to science and math education is to enable students to use the knowledge learned in the classroom flexibly. An important aim is therefore to foster the construction of knowledge structures which enable transfer to new situations. In the present study, we compared different approaches of how to introduce a novel concept in math education which is of high importance for science in general, namely learning how to determine gradients of linear functions. One way to introduce a new topic is to tell (i.e., directly instruct) learners about the concept and have them practice its application in several tasks; another way is to withhold the expository instruction and start with a preparatory constructive learning activity. These activities have been shown to better support transfer in comparison to the tell-and-practice approach (e.g., Schwartz, Chase, Oppezzo, & Chin, 2011).

We implemented contrasting cases in learning materials to prepare an expository instruction on how to determine the gradient of linear functions. Contrasting cases help to recognize deep similarities between cases

and to abstract generalizable schemata (e.g., Alfieri, Nokes, & Schunn, 2013) which in turn can enhance the effectiveness of an expository instruction (e.g., Schwartz et al., 2011). However, contrasting cases could be implemented in several different ways. First, cases can vary in concreteness. Cases could make a reference to concrete, realistic situations (e.g., using realistic concepts to label the axes of coordinate systems in which linear functions are depicted) or they could represent a concept idealized without direct reference to the real world (e.g. removing labels of the axes). Concrete cases have the advantage of activating real-world knowledge which might help to solve the task, but this activation of prior knowledge could also distract learners from deriving the underlying generic concept (e.g., Kaminski & Sloutsky, 2013). Therefore, the underlying concept might be easier to abstract from idealized cases, which however do not have the potential of activating real-world knowledge. Second, when several cases are presented simultaneously, participants should be prompted to actively compare the cases to increase transfer performance (e.g., Gick & Holyoak, 1983). Promising approaches are self-explanation prompts and prompts to invent a procedure or a formula to describe several different cases coherently. For the present research, we manipulated these two factors, concreteness of cases and kind of prompts, to construct four different preparatory learning materials and compared the transfer performance resulting from learning with these materials to a tell-and-practice condition.

### **Materials, Procedure, and Hypotheses**

All learning materials consisted of printed booklets and were randomly distributed within standard math lessons. In the preparation conditions, students started with constructive learning activities before they received expository instruction. We always presented eight cases of linear functions (i.e., 3 graphs with a positive gradient, 3 graphs with a negative gradient, and 2 graphs with a gradient of 0). Cases were either concrete or idealized and combined with either self-explanation (EXPLAIN\_CONCRETE, EXPLAIN\_IDEALIZED) or invention prompts (INVENT\_CONCRETE, INVENT\_IDEALIZED). In the CONCRETE conditions, axes of the graphs were labeled with meaningful concepts; these labels were removed in the IDEALIZED conditions. In the EXPLAIN conditions, cases were presented with a gradient (i.e. a number) that indicated the steepness of the slopes. Participants were prompted to explain how these gradients had been derived. In the INVENT conditions, cases were presented without the gradient and participants were prompted to invent a coherent method to derive an index for the steepness of the slopes. After participants finished working on the preparatory materials (for max. 30 min), these materials were removed and participants read a short instructional text on the formal definition of gradients of linear function (max. 5 min). In the tell-and-practice condition (T&P), participants read the short instructional text first (max. 5 min). Afterwards, they practiced application of the concept by computing the gradients of eight cases of linear graphs (max. 30 min).

We assessed transfer performance immediately after learning and four weeks later. The test consisted of 20 questions embedded in contexts that differed strongly in superficial details from the learning materials (e.g., physics contexts, geometry problems). Participants had 45 minutes to answer the questions. We assumed that writing self-explanations is more productively combined with concrete cases given as the context might support writing explanations, while this reference might make it more difficult to invent a method because the labeling might serve as unnecessary seductive details. Accordingly, we expected a qualitative interaction (stable over time) for the preparation conditions: INVENT\_IDEALIZED > INVENT\_CONCRETE, and EXPLAIN\_IDEALIZED < EXPLAIN\_CONCRETE. Furthermore, we expected that at least the two preparation conditions INVENT\_IDEALIZED and EXPLAIN\_CONCRETE outperform T&P.

### **Participants**

We tested 148 nine-grade students (73 female; mean age 15;6) from a Swiss town in the first week after the summer break. Linear functions are introduced in grade nine, thus, no participant had received any instruction on linear functions prior to the instructions delivered in the present study. Students were newly mixed in the ninth grade. We expected differences in prior math knowledge between students coming from different classrooms and therefore, we used the final math grades of grade eight as a covariate in all analyses.

### **Results**

Transfer questions were scored with 1 point if solved correctly, with 0.5 points if only parts of the solution were correct and with 0 points if the solution was incorrect or missing. The statistical analyses followed a two-step process. First, we computed 2 (time of transfer test: immediate vs. delayed) x 2 (concreteness: concrete vs. idealized) x 2 (prompt: invent vs. self-explain) ANCOVA (covariate: math grade) for the preparation conditions to test our hypothesis of a qualitative interaction. Second, we compared performance in the preparation conditions to T&P in a 2 (time) x 5 (condition) ANCOVA. We only report statistically significant effects with  $p < 0.05$ . The covariate strongly predicted transfer in both ANCOVAs, but did not interact with conditions.

For the preparation conditions, the ANCOVA indicated a slight decrease in transfer performance over time ( $F(1,115) = 4.2$ ,  $\eta_{partial}^2 = .04$ ). More importantly, a statistically significant concreteness x prompt interaction ( $F(1,115) = 4.0$ ,  $\eta_{partial}^2 = .03$ ) supported our hypothesis of a qualitative interaction:

INVENT\_IDEALIZED outperformed INVENT\_CONCRETE (marginal estimates means: 12.67 vs. 11.40), while SELF\_CONCRETE outperformed SELF\_IDEALIZED (marginal estimates means: 12.35 vs. 11.05). Comparing transfer performance to T&P revealed no statistically significant differences between conditions.

## Discussion

The present study in which participants learned to determine the gradient of a linear function shows that T&P is not inferior to learning materials in which expository instruction is preceded by a preparatory constructive learning activity. One explanation could be that the concept was quite easy, which might make a preparation unnecessary. For the preparation conditions, our results indicate that different kinds of prompts should be combined with different kinds of cases. Self-explanation prompts should be combined with concrete cases. A possible explanation is that this activity requires participants to describe materials and concepts in their own words; this requires the use of prior knowledge which would not be as easily available when cases are represented idealized. In contrast, invention prompts should be combined with idealized cases. We assume that this advantage emerges as the prompt is highly demanding when several cases have to be considered and idealized cases make it easier to grasp the underlying concepts. However, these interpretations would benefit from fine grained analyses of the quality of self-explanations and invented solutions. These analyses are conducted at the moment and will be presented at the conference. At the moment, the results indicate that different approaches can lead to successful transfer performance and that the T&P approach, which is popular among educators, need not to be considered a deficient instructional technique generally.

## Two Times Inventing Beats Worked Examples as Preparation for Learning from Expository Instruction

Inga Glogger, Katharina Gaus, Alexander Renkl

### Introduction and Theoretical Background

Inventing includes a generation task based on contrasting cases. More specifically, a formula or common principle is to be invented that allows for the evaluation of the cases (e.g., crowdedness of passengers in several buses). Such a generative inventing problem aims to prepare learners for subsequent expository instruction (e.g., about density; Schwartz, Chase, Oppezzo & Chin, 2011). This preparation can consist of cognitive effects, such as making aware of knowledge gaps, and motivational effects such as lifting curiosity and interest. Enhanced motivation can foster transfer. The generative processes can deepen encoding of the cases. Encoding cases (examples) deeply in an early stage of skill acquisition can foster transfer as well. On the other side, inventing activities may be problematic because learners are not directed towards the most important aspects and might (thus) not generate canonical solutions. Additionally, previous findings on inventing can often be explained by longer time-on task or weak control groups (Sweller, Kirschner & Clark, 2007). Having learners study a worked version of the inventing problem with contrasting cases (worked example) as control condition avoids these problems. In a recent study, we have actually found that enhanced self-efficacy (motivational), and less extraneous load (cognitive) in the worked example group, as compared to a inventing groups, fostered deep-structure encoding and the transfer of big ideas (Glogger, Fleischer, Grüny, & Renkl, 2013). Students, however, might have had too little experience and practice with generative tasks such as inventing (Lee & Anderson 2013). Thus, in the present experiment, we applied two inventing phases instead of one and asked if the previously found advantage of worked examples can be replicated. More specifically, we tested the following hypotheses and asked the following research questions:

1. Inventing leads to higher interest, curiosity, and perceived knowledge gaps than the worked solution.
2. The worked solution induces less extraneous load and leads to higher self-efficacy than inventing.
3. Do the two groups differ in encoding of the deep structure of preparation problems?
3. Do the two groups differ in learning outcomes (transfer)?
4. Are there process variables that mediate the effects on learning outcomes?

### Method

We randomly assigned 108 eighth-grade students (sex: 89 female;  $M_{age} = 13.62$ ,  $SD = 0.65$ ) to two conditions: inventing ( $n = 52$ ) and worked solution ( $n = 56$ ). The experiment had two preparation phases, both preparing to learn the concept of density, and moreover, of ratio indices as “big idea” in physics (the materials were adapted from Schwartz et al., 2011). The phases varied in the level of generation (inventing the solution or worked solution). In a first preparation phase, we gave three cases of different numbers of clowns that were squeezed in differently sized buses along with the task to find an index (with certain properties) for the crowdedness of the buses (the second preparation task was about gold quality). Students can discover the ratio structure of the index by comparing cases. Both experimental groups worked in pairs for 20 minutes. The inventing group invented the index. The worked example group worked on the same problem, but it was worked out: a fictional student already solved the task. Some of her thoughts were written on the worksheet. Participants were asked to explain

their solution to each other. This way, we kept communicating and debating explanations comparable; the groups differed in whether the solution was generated or worked.

We assessed extraneous load, self-efficacy, interest, epistemic curiosity, and perceived knowledge gaps by questionnaires immediately after the preparation task (see Glogger et al., 2013). Two days later, a recall test was given to measure the encoding of the deep structure during the preparation phase 1. The subsequent preparation phase 2 was about an index for gold quality, also preparing for understanding the concept of density. Students then listened to a lecture. Finally, we determined learning outcomes by calculation tasks and transfer tasks (e.g., invent density index, new cover story, or invent spring constant index, i.e., another ratio index in physics).

## Findings

Groups did not differ in interest, curiosity, self-efficacy, and knowledge gaps (all  $p > .23$ ; see Table 1 for means and standard deviations). Working on a worked-out version led to less extraneous load,  $F(1,97) = 3.47$ ,  $p = .033$  (one-tailed). Further analyses showed that this effect is mainly due to students who perceive their performance in sciences as low (significant interaction  $b = -0.181$ ,  $t(95) = -2.22$ ,  $p = .029$ ). Encoding of the deep structure of the preparation problem, measured by the recall test, was higher in the inventing group,  $F(1,97) = 6.22$ ,  $p = .008$ ,  $d = 0.54$ . The inventing group outperformed the worked solution group in transfer tasks,  $F(1,97) = 11.20$ ,  $p = .001$ ,  $d = 0.67$ . We tested mediation effects with a set of related multiple regression equations, following a products-of-coefficients strategy (MacKinnon, 2008). Encoding of deep structure mediated part of the group effect on far transfer; path A:  $b = .50$ ,  $SE = .186$ ,  $\beta = .26$ ,  $p = .008$ ,  $R^2 = .28$ ; path B:  $b = 1.14$ ,  $SE = .427$ ,  $\beta = .26$ ,  $p = .009$ ,  $R^2 = .40$ ; Sobel-test:  $z = 2.30$ ,  $p = .021$ ,  $d = 0.14$ , small effect. Deeper exploratory analyses revealed that more students found the canonical solution to the second inventing problem (56 %) than to the first (34 %), whereas self-explanations to the second worked example tended to get worse. We did not find any gender effects.

Table 1: Means (Standard Deviations) of process and outcome variables in both groups and ranges of variables.

	Inventing $M$ ( $SD$ ) ( $N = 49$ )	Worked-Example $M$ ( $SD$ ) ( $N = 50$ )	Range
Perceived Knowledge Gaps	3.72 (1.08)	3.91 (0.85)	1-6
Extraneous Load	<b>3.93</b> (0.88)	<b>3.62</b> (0.76)	1-6
Interest	3.33 (0.94)	3.41 (0.85)	1-6
Epistemic Curiosity	2.91 (0.89)	3.11 (0.73)	1-6
Self-efficacy	3.60 (2.20)	3.87 (2.32)	0-10
Recall of Deep Structure	<b>1.06</b> (1.07)	<b>0.56</b> (0.76)	0-3
Transfer	<b>8.10</b> (4.23)	<b>5.40</b> (3.79)	1-16

*Note.* Significantly different means are printed in bold.

## Discussion

In this study with two preparation phases, a higher level of generation (inventing) led to deeper encoding of the deep structure of the preparation problems. Deep encoding partly mediated transfer performance. These findings are in contrast to own previous studies (with one preparation phase), but in line with Schwartz' studies (with several preparation phases). One explanation of the effects could thus be that several preparation phases are required for inventing to be successful in comparison with a worked example. Inventing solutions got actually better in the second phase. Other studies have been shown that generation tasks need practice to be successful (Lee & Anderson, 2013).

However, we have found differences in encoding the deep structure already after the first preparation phase. A reason could be that students' practice with generative activities was already higher than in a previous sample (Glogger et al., 2013). If students need practice in generative tasks, students with higher levels of experience with generative activities, as compared to little experience, should react and benefit differently from them. We have informal hints that the present sample differed in this experience from the previous sample (teachers' reports). We compared the patterns of results of the previous study with less experienced students with the present one with more experienced students. The process variables were measured by the same items in both studies. This comparison suggests that the preparation activities elicited different processes across studies. The worked example led to significantly higher self-efficacy and less extraneous load in the previous study. Both latter variables were significant mediators of the group effect on transfer. Motivation was higher in the present sample. These different reactions towards the preparation activities could be an effect of different levels of experience with generative group activities in the two samples. However, further research is needed to systematically test this assumption.

Worked examples were shown to be most effective with a fading procedure (Renkl, 2013). In the present study, the second fully worked-out example might have reduced interest, curiosity, and deeper processing because there was no fading. Subsequent studies could use a fading procedure and further look at beneficial motivational and cognitive processes during a preparation activity. In sum, this experiment suggests that students' transfer of big ideas in physics is best fostered by several phases of a generative task such as inventing instead of several worked examples.

## Does Collaboration Affect Learning in a Productive Failure Setting?

Claudia Mazziotti, Katharina Loibl, Nikol Rummel

### Introduction and Theoretical Background

Researchers as well as practitioners struggle with the so called assistance dilemma, which targets the question of the timing and degree of assistance that students should receive when learning new concepts and procedures. Some researchers argue that a high degree of assistance in form of instruction should be provided at the beginning of the learning process to avoid a high level of cognitive load (Kirschner, Sweller, & Clark, 2006). Others claim that at the beginning of the learning process students should be enabled to discover new concepts and procedures on their own (i.e., low degree of assistance) to support the acquisition of conceptual knowledge (e.g., Schwartz & Martin, 2004; Kapur, 2012). One representative of this group is Manu Kapur with his two-phase instructional design of Productive Failure (PF) (e.g., Kapur, 2012): In the first phase, small groups of students try to solve a new problem on their own. During this problem-solving phase they usually generate incomplete or erroneous solution ideas. In the second phase, students receive instruction on the canonical solution in a class session (instruction phase). It has been discussed that PF designs trigger the following learning mechanisms (e.g., Kapur, 2012): First, students' problem-solving attempts prompt the activation of prior knowledge. Second, during instruction students focus their attention on the components of the target concepts that they did not yet discover during the problem-solving phase. Additionally, Loibl and Rummel (2013) argue that the form of instruction is crucial for learning: During the instruction phase, the teacher can build upon students' generated solution ideas by comparing these ideas to each other and contrasting them with the canonical solution. Loibl and Rummel (2013) showed that this form of instruction was more effective than instruction focusing on the canonical problem-solving procedure and the underlying concept.

While the effects of the timing and the form of instructions on the acquisition of conceptual knowledge are studied well, the role of collaboration during the first phase of PF remains unclear (Collins, 2012). Against the background of research on collaborative learning, we assume positive effects of trying to solve a problem collaboratively, because in a collaborative learning setting students are encouraged to verbalize and explain their problem-solving ideas to each other (Slavin, 1996). In this way, elaborative processes and sense-making activities are initiated, which in turn support the acquisition of conceptual knowledge (Cohen, 1994). Indeed, Mullins, Rummel, and Spada (2011) showed that trying to solve a problem collaboratively is more efficient for the acquisition of conceptual knowledge than individual problem solving. However, research on collaborative learning has also emphasized that students need collaboration support (e.g., a role script, a group goal) to ensure fruitful interaction (Slavin, 1996; Cohen, 1994). Against this background, we hypothesize that learning collaboratively during the first phase of PF facilitates the acquisition of conceptual knowledge in comparison to individual learning (hypothesis 1). Given that several studies with secondary school students or university students could show that PF designs foster conceptual knowledge and transfer in comparison to expository instruction conditions (e.g., Schwartz & Martin, 2004; Kapur, 2012), we further investigated whether the beneficial effect of PF on the acquisition of conceptual knowledge can be replicated with elementary school students (hypothesis 2).

### Method

In order to test our hypotheses, we conducted a quasi-experimental study with 4<sup>th</sup> graders ( $N = 55$ ; age 10) in Germany. Overall, we installed three conditions: We implemented two PF conditions as they were described above differing only in the social form during the problem-solving phase (i.e., PFCo = problem solving in dyads; PFIn = individual problem solving). As a control condition, we set up a third condition (EICo), in which students received instruction first. As in the PF conditions, the experimenter compared and contrasted typical student solutions, which were collected prior to the experiment during pilot studies. Afterwards students solved an isomorphic problem collaboratively. In both collaborative conditions (PFCo & EICo) we supported the collaboration via a role script ("thinker" and "asker") and a group goal (the pair who collaborated best won a price). During the collaboration students were videotaped. The to-be-solved problem was a story problem requiring expanding two fractions to compare them. Prior to the first learning phase, all students answered a pretest measuring students' mathematical prerequisites. After the second phase, students answered a posttest measuring conceptual knowledge of the target concept. The study took place on two days (45 minutes per day)

and the three classes were assigned to the three conditions as a whole. In all classes, students have not learnt fraction expansion and comparison prior to the study.

## Results

Only the 52 students who were present during both learning phases were included in the analyses. To assess differences between the experimental conditions, we calculated an ANCOVA with the factor condition and the covariate pretest score (i.e., mathematical prerequisites). Mean scores and standard deviation of the three conditions are displayed in Table 1. We did not find significant differences between the three conditions ( $F[3,48] = 2.3, p = .11$ ). We further defined two a priori contrasts in line with our hypotheses. The first a priori contrast compared PFCo and PFIn to test the effect of collaboration (hypothesis 1). For this contrast, we did not find significant differences between conditions ( $F[1,48] = 0.4, p = .84$ ). The second a priori contrast compared both PF conditions to EICo to test if the PF effect can be replicated for young children (hypothesis 2). This comparison revealed a significant difference between EICo and the two PF conditions ( $F[1,48] = 4.6, p = .03$ ), favoring the PF conditions.

Table 1: Mean scores and standard deviations of the posttest.

	<i>N</i>	<i>Mean</i>	<i>SD</i>
PFCo	16	7.88	5.43
PFIn	17	7.71	3.29
EICo	19	5.26	3.91

## Discussion and Outlook

In summary, we investigated two hypotheses: Our main hypothesis, that collaborative problem solving within the first phase of PF is more beneficial for learning than individual problem solving, could not be confirmed by our findings. This result is surprising considering the above mentioned beneficial effects of collaborative learning on the acquisition of conceptual knowledge. Although we implemented a group goal and a role script to support the collaboration, it seems that students did not take advantage of the collaborative setting. The analysis of the video data will provide insights on the quality of students' collaboration. Given the high SD in the PFCo condition we assume that the quality of collaboration differed strongly across dyads and moderated the effect of collaboration on conceptual knowledge. Hence, for future work we aim to intensify our efforts to implement a collaborative support structure (e.g., by implementing a training for collaborative learning). Our additional hypothesis, that also for young students PF is more beneficial for the acquisition of conceptual knowledge than expository instruction, could be confirmed. In other words, this finding replicated other PF studies (e.g., Kapur, 2012; Loibl & Rummel, 2013) with a younger age group.

Due to the small sample size we should treat our results as preliminary. We plan to conduct a follow-up study with a 2x2 design with the factors timing of instructions and social form. With this study we aim at determining whether the possible effect of collaborative learning interacts with the timing of instructions.

## Using Contrasting Cases for Generation and Instruction

Nicole R. Hallinen, Doris B. Chin, Kristen P. Blair, Daniel L. Schwartz

### Contrasting Cases

An important part of science and math education is the learning of functional relations among variables. These ideas map to Mathematical Practices in the Common Core State Standards (e.g. *Reason abstractly and quantitatively; Look for and make use of structure*), as well as the Ratio & Proportion Content area throughout middle school grades (National Governors Association Center for Best Practices, 2010). In science assessments, it has been shown that 4<sup>th</sup> grade students who know about functional relations between plant growth and amount of light are better able to explain their answers, indicating that this knowledge affects a students' ability to express his or her understanding (NCES, 2012).

*Contrasting cases* are instructional tools that, in our instantiation, present a series of examples of a phenomenon; they are particularly well-suited to the task of highlighting variation to show functional relations. During these short, inductive activities, students learn to appreciate the range of variation in a problem space and also notice the invariant relationship that underlies each example. Contrasting cases have been developed for a number of STEM topics, such as statistical variation (Schwartz & Martin, 2004), electromagnetic fields (Chase, Shemwell, & Schwartz, 2010), and density and other ratio-based topics (Schwartz, Chase, Oppezzo, & Chin, 2011), and for use with audiences ranging from 4<sup>th</sup> grade to graduate students.

Our research focuses on two aspects of using contrasting cases in math and science instruction: task orientation and design of materials. In both topics, we measure the effectiveness of using contrasting to learn about scientific relationships and eventually transfer these ideas to new topics.

### Task Orientation

To use contrasting cases in instruction, educators must instill the proper task orientation in students. We find that encouraging students to adopt an “inventing” task orientation is productive for discovering important features and patterns among the examples shown.

In a study conducted in an 8<sup>th</sup> grade classroom, contrasting cases were used to teach students about the underlying concept of ratio, an important idea that relates to many ideas in middle school science and mathematics topics, such as density, and speed. Some students were taught about ratios first and told to use this knowledge to compute ratios about the contrasting cases. Another condition was asked to invent an index to describe the cases. In the inventing condition, students invented the ratio structure of density and speed. The students who invented the ratio idea transferred the concept to the spring constant, a new domain, on the posttest (Schwartz et al., 2011). The students who were explicitly taught about computing density and speed did not see the underlying ratio structure across examples, which led to lower transfer. This finding is in line with other research showing that students fail to notice commonalities across problems when instances are presented sequentially (Star & Rittle-Johnson, 2009).

A different study with 40 6<sup>th</sup> grade students used a set of contrasting cases to teach the relationships among range, hang time, and speed in projectile motion. In this between-subjects study, one condition was asked Compare and Contrast (CC) the cases. The other condition was instructed to use the same set of cases to Invent (INV) a method to predict the range of any shot. The CC students focused on isolating individual components of projectile motion for comparison and were less likely to create an explanation that linked all three factors (range, time, and speed) than the INV condition. As a result, INV students outperformed their CC peers on a posttest about predicting the range of a projectile. Compare and Contrast instructions were simply not sufficient for learning structural relationships from contrasting cases; activities must ask students to generalize. (Chi et al., 2012)

These examples highlight the benefit of encouraging students to search for a general solution. In each study, the same contrasting cases materials were provided to each condition, indicating that task orientation provides additional support for learning beyond the cases themselves.

### Designing Contrasting Cases Materials

Even with the right task orientation, students need well-designed materials to support learning. The examples included in sets of contrasting cases for multivariate topics must show varying levels of each factor as well as the variety of possible combinations of variables that contribute to the solution. Fifty community college students participated in a recent study to investigate the effects of using different materials to learn early physics concepts.

For this study, we designed two sets of contrasting cases showing two-dimensional inelastic collisions. The result of each collision (move left, right, or stop) is determined by comparing the momentum (mass \* speed) of the objects. We manipulated the examples as shown in Figure 1A. Individuals in the *Main Effects* (ME) condition received cases that isolate the main effects relationships between the two variables – cases where mass or speed is held constant across the two objects, or where mass and speed both indicate the same result. In the *Main Effects + Interaction* (ME+I) condition, some cases showing interaction relationships between the two key variables were included. In these cases, attending only to mass or only to speed would be insufficient to determine the result.

In a transfer task, participants in both conditions received contrasting cases for the balance scale, an analogous science domain in which torque must be calculated by multiplying mass and distance from the fulcrum to determine whether the scale balances or tips. These cases included main effects and interaction cases, showing enough variation that simple qualitative rules about mass and distance would not be sufficient to explain the results. These cases are shown in Figure 1B, with the interaction cases outlined for the reader. The worksheet that students saw did not include this outlining.

We found that using the ME collision materials led to a qualitative understanding of the relationship between mass and speed. Participants who receive the ME+I materials were more likely to find the multiplicative relationship between the variables, and, in turn, performed better on a set of 18 prediction questions ( $t(32) = -3.14, p < 0.01$ ).

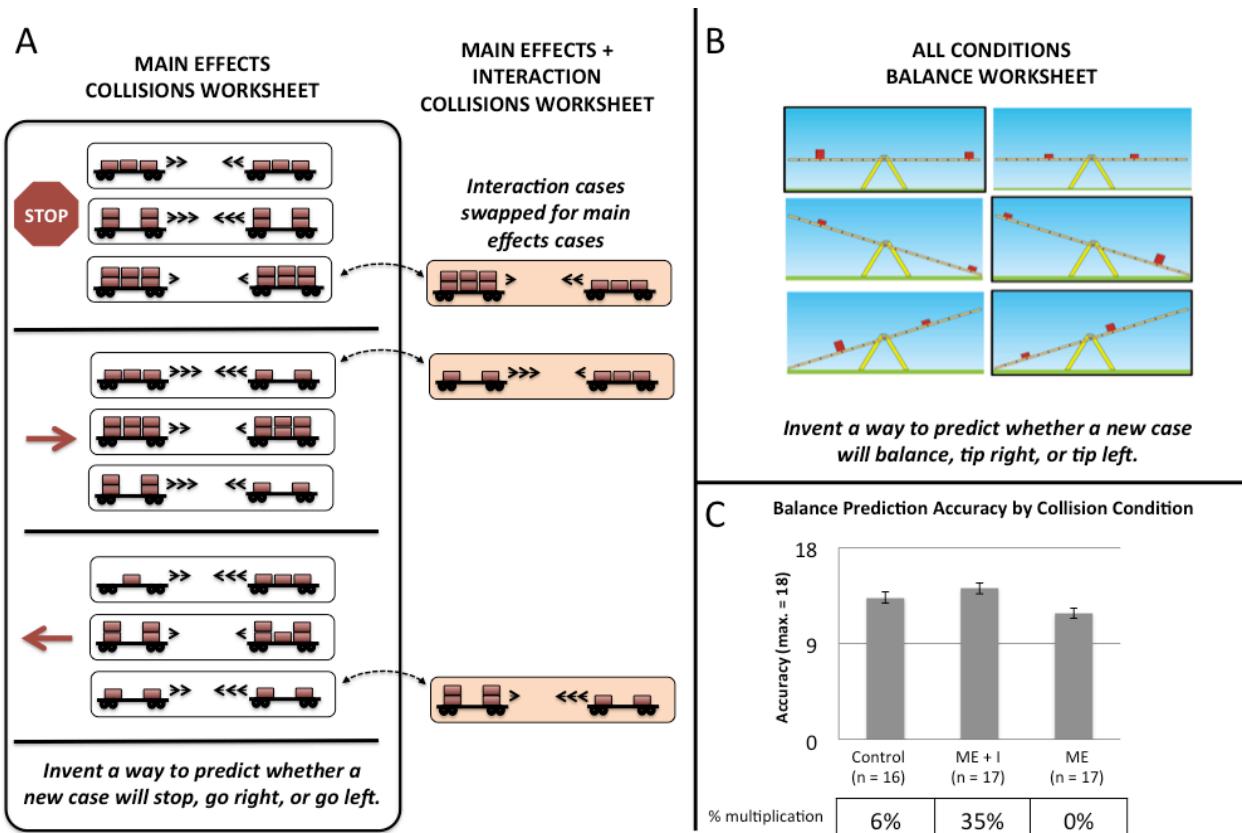


Figure 1. Contrasting cases materials for A) momentum and B) torque. C) Transfer task results.

As shown in Figure 1C, participants who used the momentum ME materials learned less from the transfer balance scale cases (0% found a multiplicative solution). They also performed worse on balance scale prediction questions than their ME+I counterparts. In fact, they performed even lower than control students who did not do the momentum activity at all. Using ME materials resulted in negative transfer to a new content area.

This result demonstrates that the effects of using incomplete examples extend beyond one topic and can impact learning on future problem solving tasks. Therefore, educators should carefully choose contrasting cases that systematically demonstrate the structural relationships between variables in these multivariate conceptual domains.

## Conclusion

Contrasting cases have the potential to facilitate a deep learning and eventual transfer of quantitative structures, such as ratio, that recur throughout science and math curricula various science and math topics. As demonstrated, instructional designers must thoughtfully select cases to show the range of possible variability. Additionally, the studies reviewed here emphasize the utility of adopting an “inventing” task orientation for learning from contrasting cases. We suggest that the combination of well-chosen materials and an explicit focus on invention and generalization are two key aspects of using contrasting cases to promote learning across STEM domains.

## Discussant

Katherine McElloon, Learning Sciences Institute, Arizona State University  
(Chairperson: Inga Gloger, University of Freiburg)

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# The Interplay of Domain-Specific and Domain-General Factors in Scientific Reasoning and Argumentation

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**Abstract:** This symposium raises the issue of the role of domain-general factors in scientific reasoning and argumentation tasks. The contributions cover conceptual problems concerning the interplay of general and specific elements in scientific reasoning, methodological requirements and existing research paradigms for investigating the role of cross-domain factors in scientific reasoning and argumentation tasks, limitations of domain-general epistemic criteria in the context of evaluating competing explanations and evidence, and experimental evidence exploring the limits of domain-generality in the context of interventions designed to foster scientific reasoning. The symposium includes a technology-supported interactive discussion with the audience.

## Introduction

Argumentation and scientific reasoning are often included among the crucial skills that students need in order to master the challenges of a knowledge society in the 21st century. These skills are typically conceived of as broadly applicable and largely domain-independent.

However, the idea of cross-domain skills has been challenged more generally from several directions. First, research in personality psychology has showcased so-called “general cognitive abilities” (i. e. intelligence) as the single domain-independent factor in the explanation of performance variation among persons in cognitive tasks across fields, including scientific reasoning and argumentation. Second, research originating from cognitive psychology has emphasized the amount and quality of highly domain-specific experiences as a major explanatory variable for skilled performance. In particular, expertise research has provided strong evidence for the dominating role of years of deliberate practice for developing highly domain-specific excellence (Ericsson, 2006). Third, the situated cognition approach has advanced the idea that knowledge is tied to activities in specific contexts and cannot easily be transferred to different activities (e. g., Greeno, 1998). This symposium takes on the issue of the existence and the role of domain-general factors for performance in scientific reasoning and argumentation tasks. A particular focus will be on the relationship and the interplay of domain-general and domain-specific factors in these tasks.

In the first contribution, Jonathan Osborn questions the tenability of scientific reasoning as domain-general. As further problems he identifies the failure to take the role of knowledge in scientific reasoning into account, a lack of reconciliation of partly complementary perspectives of researchers from different disciplines, as well as a lack of focus on critique as an important component of scientific reasoning.

Second, Christof Wecker, Andreas Hetmanek, and Frank Fischer first discuss the methodological requirements for empirical research that purports to demonstrate or disprove the existence of cross-domain skills of scientific reasoning and argumentation. Then they identify three research paradigms and review exemplary studies from each of them, including research of their own, which all suggest that cross-domain skills may actually play a role in scientific reasoning and argumentation.

Third, Clark Chinn, Ravit Golan Duncan, and Ronald Rinehart set out to theoretically explore the interplay of domain-general and domain-specific factors, and particularly, of the ways in which domain-general knowledge can and cannot be used across domains or topics depending on the domain-specific knowledge available. Drawing on findings from the PRACCIS (Promoting Reasoning and Conceptual Change in Science) project, they show how students both are able to develop sets of epistemic criteria that they attempt to apply

across domains, and struggle actually applying these criteria across domains. Failure to identify referents for the criteria, referent misidentification, and narrow knowledge are identified as the major obstacles.

In the fourth contribution, Stephanie Siler and David Klahr turn to the issue of how domain-general skills are learned, and to the role of domain-specific examples in this process. In an experimental study they could show that, across the board, students made the least progress if they first evaluated experiments that were represented in an abstract fashion (no specific values for independent variables mentioned) and then experiments that were represented in a concrete fashion (specific values of independent variables mentioned). Younger and lower-ability students showed better transfer in an all-concrete condition than in a concrete-fading condition. Domain-specific information appears to be critical for acquiring domain-general skills.

Finally, the discussant William Sandoval will identify specific and common issues in the different contributions, bring in his own perspective on the topic, and start the discussion with the audience. To facilitate interaction with the audience, we will use Web-based audience response technology and ask the audience to write comments and reactions via their smart phones or computers during the individual presentations. One of the co-authors of this symposium will monitor contributions from the audience and provide a summary of the reactions directly after the presentation. In addition, one or two issues that seem specifically thought-provoking may be highlighted and the presenter may be asked to respond to it. In addition, the discussant will raise more general, overarching issues, to which every presenter can briefly respond. The audience will again be invited to contribute further, more overarching questions and arguments.

## **Teaching Scientific Reasoning: The Ineluctable in Search of the Ineffable?**

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Ever since its inception, one justification for science education has been that it might educate the neophyte student in the highly-valued, disciplinary habits of mind of the scientist (DeBoer, 1991; Dewey, 1916; Layton, 1973; Turner, 1927). In contemporary society where information is readily available, such arguments have become more pre-eminent. Hill (2008), for instance, has argued that the societies that sustain their competitive edge in the coming decades will be ‘post-scientific’ societies. In such a society, highly valued skills will be the ability to draw on a range of disciplinary knowledge, to think creatively and to evaluate new ideas in a critical, reflective and rational manner. Employers will require individuals who, while having a core understanding of scientific and technical principles, have the ability to communicate and synthesize knowledge in an original manner. Similar arguments can be found in the recent NRC (2012) report which argues that it is important to develop three domains of competence – the cognitive, the intrapersonal, and the interpersonal. Gilbert puts it even more straightforwardly arguing that ‘in a world where there is an oversupply of information, the ability to make sense of information is now the scarce resource’ (Gilbert, 2005). Central to developing students’ ability to undertake the cognitive process of complex reasoning is the ability to think critically and analytically, tackle non-routine problems, and construct and evaluate evidence-based arguments. In the case of science education, then, it is important to ‘be certain that we emphasize what we want, for we shall surely get what we emphasize’ (Hill, 2008). However, science education has suffered from a lack of clarity about ‘what we want’ and how to build student competency with scientific reasoning. Drawing on a historical analysis this paper identifies four problems have confounded the field each of which is elaborated beneath. The paper then offers a model of scientific reasoning which addresses each of these concerns.

### **Problem 1: The Disjuncture between Domain-Specific and Domain-General Conceptions of Scientific Reasoning**

The first problem is a product of the failure to identify the *domain specific* and disciplinary nature of scientific reasoning. Whilst this may seem self-evident to science educators, many attempts to define scientific reasoning have emphasized scientific reasoning as a *domain general* concept. One version of this is seen among psychologists who commonly take a ‘nothing-special view’ (Simon, 1966) arguing that general reasoning abilities can account for the main characteristics of scientific reasoning, and that these are more important as they are *transferable*. Klahr and Simon (1999), for example, acknowledge that domain-specific aspects are the basis for ‘strong methods’ within the sciences, but claim that these only have limited value because they apply to well-defined contexts and problems. Instead, they contend that, when scientists move into new areas and meet ill-defined problems, general strategies or ‘weak methods’ are the most important forms of reasoning.

The contrary argument, however, has been made both within psychology and science education. Perkins and Salomon (1989), for instance, made a seminal argument that ‘general heuristics that fail to make contact with a rich domain-specific knowledge base are weak’ and that ‘a domain-specific knowledge base without general heuristics...is brittle’ (p. 24). Within science education, Passmore and Stewart (2002), for instance, have argued that ‘scientific practice is discipline specific’ (p. 187). Likewise, Sandoval and Morrison (2003) conclude from their analysis of student explanations of Galapagos data ‘that epistemic and conceptual understanding are tightly interrelated.’ (p. 48)

Defining scientific reasoning either as domain general cognitive skill is both flawed and unsustainable. It is flawed because it misrepresents the nature of scientific reasoning as, while individuals in everyday situations may use reasoning akin to that of scientists, such forms of reasoning can not be used to *define* what is distinct about scientific reasoning. Similarly, arguments for the value of teaching domain-general reasoning within science are unsustainable because general reasoning does not *have to* be taught in science. A logical consequence of this view is that science education is in need of a conception for scientific reasoning that identifies its *domain specific* characteristics more uniquely.

### **Problem 2: The Failure to Identify the Role of Knowledge in Scientific Reasoning**

This problem has challenged cognitive psychology since the late 1950s, when researchers made provocative comments about reasoning skills being *knowledge-independent*, or, as expressed by Inhelder and Piaget (1958) as a facility which was to be seen as ‘liberated from particular contents’. While most psychologists today admit that reasoning is knowledge-dependent (Zimmerman, 2007), many have continued to study domain-general reasoning processes in *knowledge-lean* tasks (problem 1).

From a disciplinary perspective, such a position is not satisfactory as domain-specific knowledge should be at the heart of scientific reasoning. What, for instance, are the domain-specific entities used by the individual when reasoning within the domain? Undoubtedly, a factor that has changed over the past six decades is the development in our understanding of what we mean by knowledge – a development that can be illustrated by the changes that have occurred in Bloom’s (1956) taxonomy of cognitive processes when compared to the revised version offered by Anderson & Krathwohl (2001). These authors split reasoning into two dimensions, a knowledge dimension and a cognitive process dimension, and use not one but four categories to describe their knowledge dimension: factual knowledge, conceptual knowledge, procedural knowledge and metacognitive knowledge. Likewise, Li and Shavelson (2001) have used a similar framework splitting knowledge into declarative knowledge (knowing what), procedural knowledge (knowing how), schematic knowledge (knowing why), and strategic knowledge (knowing when, where, how knowledge applies) – a perspective that was influential in developing the NAEP 2009 framework for assessment in science. The common point in these and other examples is that they alter the way we conceptualize the relationship between knowledge and reasoning. That is, what used to be explained as a generic ‘reasoning skill’ linked only weakly to a body of undifferentiated knowledge is now dependent on a set of distinctive aspects of domain-specific knowledge of ‘what we know’, ‘how we know’ and ‘why it happens’.

### **Problem 3: The Differing Perspectives of Psychologists and Philosophers**

In academic research, the most conspicuous difference in accounts of scientific reasoning is between psychological and philosophical definitions. Psychologists approach the study of reasoning in a descriptive way with a focus on cognitive processes and abilities. Sociologists, likewise, are equally descriptive but their focus is on the social practices that enable the constitution of new knowledge. Philosophers in contrast take a normative perspective focusing more on the epistemological principles and values intrinsic to the reasoning. In one sense psychologists are more concerned with *how* someone reasons, while philosophers and sociologists seek to understand *why* they reason as they do and how they justify scientific belief, albeit from very different perspectives (Bailin & Siegel, 2003). While philosophers, sociologists and psychologists may find their differences tolerable, educators cannot. As Millar and Driver (1987) have shown, any educational ‘definition’ of scientific reasoning has to give a ‘correct’ picture of science in that it: first adequately represents the common reasoning practices of science; second, aligns with current thinking in the learning sciences; and third, ‘works’ in the sense that it does not place unreasonable expectations on either students or teachers. The need for a ‘correct picture’ is justified because teaching of scientific reasoning is also teaching *about* science, and it ‘seems unwise, to say the least, to develop a rationale for school science upon a view of science which is seriously at odds with current thinking’ (p. 45). However, in the history of science education rarely have the insights offered by philosophy, sociology and psychology been brought together. Consequently, ‘merging’ these perspectives on scientific reasoning to create a rationale that informs educational practice has been a goal of recent work – the aspiration being to develop a conception that is more workable in the classroom.

### **Problem 4: The Absence of Critique**

The fourth problem is the failure to recognize the role and value of critique in the construction of knowledge. The practice of science requires a dialectic between construction and critique (Ford, 2008). The two activities are thus mutually dependent and any account of scientific reasoning to be offered in the classroom must incorporate a means of acknowledging the centrality of critique. The argument here is that ideas are rarely considered in isolation and that a Bayesian account (Howson & Urbach, 2006) of reasoning offers a better model of scientific reasoning. For instance, persuading a student of the validity of the scientific account is as much a task of demonstrating why alternate ideas are flawed as one of demonstrating why the scientific idea might be right and adjusting the balance of their beliefs. Developing any understanding of the centrality to

critique to scientific reasoning requires it to be a common feature of the science classroom. However, the dominance of construction means that it is almost an absent feature of common pedagogic practice. One consequence, as empirical evidence from our work on developing a learning progression for argumentation shows which will be presented, is that students find engaging in critique harder than engaging in construction (Osborne et al., 2013).

To address all four of these problems, a model for scientific reasoning is proposed. This seeks to combine both the philosophical model of reasoning presented by Giere et al. (2006), and the psychological model of science as a process dependent on working in two search spaces developed by Klahr and Dunbar (1988). This model emphasizes three fundamental spheres of activity which require scientific reasoning: the development of theoretical models and hypotheses (developing explanations and solutions); the testing of hypotheses against using data gathered from the ‘real world’ (investigation); and the coordination and evaluation of the outcomes from these two domains of activity (evaluating).

The most coherent account of the nature of scientific reasoning emerges from those historians who offer a cognitive history of science (Crombie, 1994, Netz, 1999) that identifies 6 distinctive forms of reasoning *within science*. Crombie argues that these styles of reasoning have no foundation – they are just how we reason in science and are an emergent feature of the socio-cultural context where they were first developed. Each of these forms of reasoning brings into being a set of ontic, procedural and epistemic entities that are required to perform the reasoning – each of which are *domain specific*. In this presentation, it is argued that the recognition of the forms of reasoning intrinsic to science, and the spheres of activity in which they are conducted, provides not only a better argument for what should be taught but also how it should be taught.

## **Do Cross-Domain Skills of Scientific Reasoning and Argumentation Exist?**

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In this symposium, the present contribution has the function of (1) specifying the requirements that need to be imposed on empirical evidence in favour of the existence of cross-domain skills such as the skills of argumentation or scientific reasoning, (2) discussing research, including our own, from three different paradigms that may provide evidence in favour of the existence of cross-domain skills, and (3) formulating consequences and directions for future research.

### **Requirements for Empirical Evidence in Favour of Cross-Domain Skills**

To specify the requirements that need to be imposed on empirical evidence in favour of the existence of cross-domain skills, we need to consider the “logic of skills”: “Skill” (the terms “competence”, “ability” could be used synonymously) is a dispositional concept (Heider, 1958, ch. 4), i. e. the property of a person, which it describes, is manifested in a specific kind of performance in specific situations. For instance, to state that *somebody has the skill to perform a hypothesis test* means that he or she will manage to conduct an adequate hypothesis test if he or she is motivated and has the opportunity (including that appropriate tools and materials are available) to do so (cf. Heider, 1958, ch. 4). Thus, skill is an explanatory factor of performance beyond opportunity and motivation.

However, the skill component involved in the explanation of a certain kind of performance is not a monolithic entity that is tied to the particular kind of action in a one-to-one fashion; the quality of hypothesis testing performed by different persons may differ if one person (a) has more knowledge about the topic than the other person; (b) excels on almost any cognitive tasks while the other struggles with most cognitive challenges; (c) has better skills in operations that are conducted during hypothesis testing. In other words, given the same motivation and opportunity, performance varies as a function of domain-specific knowledge, intelligence, and skills that are not tied to a particular domain, i. e. cross-domain skills.

Ironically, each of the explanatory factors of performance except one has its advocates in psychological research: Domain-specific knowledge (expertise research) and intelligence (differential psychology), but also motivation (motivational psychology) and opportunity (situated cognition, socio-cultural approach, activity theory), are all well respected factors in explaining performance. The only factor that has remained elusive and the existence of which has been questioned repeatedly are cross-domain skills. A reason for this may be that so far research has failed to provide a compelling account for explaining this factor itself, as compared to the accounts that have been suggested for domain-specific knowledge (e. g. as individual chunks or schemata within a simulation framework for human cognitive architecture, see, e. g., Anderson & Lebiere, 1998) and intelligence (e. g. as certain aspects of working memory capacity, see, e. g., Kyllonen & Christal, 1990). At the same time, the criteria for empirically demonstrating the existence of cross-domain skills are completely parallel to those for each of the other factors. Hence, the question whether cross-domain skills of scientific reasoning and argumentation exist can be operationalized – with increasing specificity – in the following ways:

Are there any data showing that

- (i) some people systematically outperform other people with identical opportunity, motivation, intelligence, and domain-specific knowledge in scientific reasoning or argumentation tasks?
- (ii) some people systematically outperform other people with identical opportunity, motivation, intelligence, and domain-specific knowledge in scientific reasoning or argumentation tasks from at least two different domains?
- (iii) the degree to which some people systematically outperform other people with identical opportunity, motivation, intelligence, and domain-specific knowledge on a scientific reasoning or argumentation task from one specific domain is correlated with certain “strategic” knowledge that does not contain any reference to specific knowledge from the domain of the task?

A positive answer to the first question would imply that performance is not explained by intelligence and domain-specific knowledge alone. A positive answer to the second question would imply that the explanatory factor beyond intelligence and domain-specific-knowledge is in fact not tied to a particular domain. A positive answer to the third question would involve insights about the nature of the strategic knowledge underlying a particular cross-domain skill.

### **Research Evidence from Three Paradigms in Favour of the Existence of Cross-Domain Skills of Argumentation and Scientific Reasoning**

We can conceive of three research paradigms that can provide evidence pertinent to the question of whether there are any cross-domain skills, in particular with respect to argumentation and scientific reasoning:

- (i) research on expert performance in a domain that falls outside of their particular area of expertise but still has some similarities to it,
- (ii) well-controlled experimental studies about interventions demonstrating effects on transfer tasks from a different domain than the one used during the interventions themselves, and
- (iii) correlational studies on predictors of performance controlling for competing explanatory factors and trying to explain variance in performance by means of cross-domain dispositions or, more specifically, skills.

In the following, we briefly discuss some exemplary findings from these three paradigms before presenting the findings from our own research that can be subsumed under the correlational approach.

#### **Expert Studies**

Schunn and Anderson (1999) found that in scientific reasoning tasks such as experimental design and analysis, psychologists from an area unrelated to the specific tasks by far outperformed undergraduates despite similar levels of domain-specific expertise. This finding is incompatible with the view that performance differences in scientific reasoning can be explained by highly domain-specific expertise.

#### **Transfer Studies**

Klahr and colleagues have repeatedly shown in strong experimental designs that certain aspects of scientific reasoning – i. e., the control of variables strategy – can be efficiently trained using an explicit teaching approach, and that typically learners from the training conditions by far outperform learners from control groups on control of variable tasks from topical areas that were not covered in the training phase (e. g., Klahr & Nigam, 2004). These findings are incompatible with the position that domain-specific knowledge and intelligence alone can account for performance differences in scientific reasoning.

#### **Correlational Studies**

Stanovich and West (1997) showed that individual differences in college students’ performance in evaluating arguments concerning real-life situations are reliably linked not only to individual differences in intelligence, but also to a habit of actively open-minded thinking: Actively open-minded thinking remained a significant predictor even after individual differences in intelligence had been partialled out (Stanovich & West, 1997, p. 342). These kinds of analyses show that cross-domain dispositions can be a relevant explanatory factor. However, the authors characterized this further explanatory factor as a habit rather than as a skill or some kind of strategic knowledge underlying a cross-domain skill.

To generate evidence demonstrating that strategic knowledge can be an important factor (see (3) above), we conducted a study with a similar design, but with an additional cross-domain strategic knowledge factor to bind unexplained variance. In particular, we wanted to provide evidence for the role of argumentation strategy knowledge as a further explanatory factor for performance in argumentation tasks while controlling for general cognitive abilities and domain-specific knowledge. The participants in this study were 123 university students who completed online tests for the three predictor variables and produced written arguments in favour

of their opinion concerning energy supply. Using structural equation modeling, we were able to show that after controlling for general cognitive abilities and domain-specific knowledge, argumentation strategy knowledge still significantly contributes to the explanation of performance variation in argumentation tasks. Furthermore, multiple-group analysis revealed that this relation between argumentation strategy knowledge and performance in argumentation tasks holds only for learners with domain-specific knowledge above a certain minimal threshold, which is in line with the idea that cross-domain skills such as argumentation strategies require a certain minimal amount of domain-specific knowledge upon which they can operate (cf. Alexander & Judy, 1988, p. 384). So far, the available evidence applies primarily to novices. It is not unlikely that the explanatory power of cross-domain skills may be marginalized with increasing expertise in a specific domain.

Nevertheless, these findings are inconsistent with the view that performance differences in argumentation can be accounted for by domain-specific knowledge and intelligence alone and that cross-domain strategic knowledge does not contribute to their explanation. Hence, this study provides evidence for the existence of cross-domain scientific reasoning and argumentation skills.

## Conclusions

The question of whether cross-domain skills such as those of scientific reasoning and argumentation exist has been highly contested and answered differently across time. It appears that sometimes researchers tend to overemphasize the factor on which they focus in their own research as the main or even sole explanatory factor. Not as much in published work as in less formal venues, such as when acting as a reviewer for a journal or as a discussant at a conference, this view may be manifested as outright denial of the existence cross-of domain skills. Therefore, in this contribution we have thoroughly analyzed the methodological criteria that need to be imposed on research pertaining to the existence or non-existence of such cross-domain skills of scientific reasoning and argumentation, and we have identified three appropriate research paradigms for studying this question. We have presented results from these three paradigms as well as research of our own speaking in favour of the existence of cross-domain skills of scientific reasoning and argumentation. There is some indication that quasi-formal argumentative strategy knowledge may underlie these cross-domain skills.

Future research on cross-domain skills of scientific reasoning and argumentation should be based on a comprehensive theoretical framework of explanatory factors for performance such as the one sketched in this contribution, and exhibit the methodological sophistication that is necessary to rule out alternative explanatory factors. The operationalization of the general research question and the typology of research paradigms suggested in this contribution may be used as a starting point in this respect. Thus, it will be possible to focus more deeply on the interplay of cross-domain skills with domain-specific knowledge in explaining performance in scientific reasoning and argumentation tasks.

## Epistemic Criteria: How Far Does General Knowledge Get You?

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### The Problem

A core premise of much work in the learning sciences is that domain and topic knowledge are intimately involved in learning and reasoning processes. This poses a serious challenge to the assumption of many educational researchers that it is possible to teach students general skills or strategies that can be widely used across different topics and disciplines (e.g. Sadler & Donelley, 2006; von Aufschnaiter et al., 2008). For example, there continues to be broad interest in teaching skills (critical thinking, collaboration, control of variables) that are generally applicable. Similarly, science education research on promoting understanding of the nature of science (NOS) seems to posit that there is general knowledge about science that can be profitably taught. In contrast, proponents of the domain specificity of thinking argue that thinking differs so much from one domain to another that there is little point in attempting to teach anything general (e.g., Willingham, 2007).

Our goal is to work toward a theoretical analysis of ways in which general knowledge can and cannot be used across different domains or topics. We focus on epistemic practices given their importance to human knowledge development and their tight connection with the theme of this conference. We think that the debate on whether general epistemic practices exist, and can be productively taught, would profit from a more detailed theoretical analysis of what a person might gain through general knowledge of reasoning practices.

We draw on our experience in the PRACCIS project (Chinn et al., 2008; Duncan et al., 2011) working with middle school students engaged in extensive model-based inquiry instruction (several months to a full year in four separate implementations). One feature of PRACCIS is the development of epistemic criteria by classes. We have found that students readily develop class lists of epistemic criteria for evaluating models such as “good models fit all the good evidence” and “good models show all the steps in the process,” and “good models are easy to understand.” They can also develop criteria for good evidence such as “good evidence helps you decide which model is better” and “good evidence uses control groups.” These criteria are used in conjunction with

learning the content of a domain (e.g. genetics, natural selection). Here we consider some potential limitations of epistemic criteria in evaluating models and evidence.

### **The Limitations of General Knowledge of Epistemic Criteria**

What are the limits of general knowledge of epistemic criteria? To answer this we first consider the situation in which a student tries to apply knowledge of such criteria to new domain with which they are fairly familiar. Two major difficulties that can arise in this situation: (1) *overgeneralization* and (2) *undergeneralization*. These problems are discussed in the literature on transfer (e.g., Schwartz et al, 2012). In the domain of epistemic criteria, we propose what we believe to be new solutions to these problems.

As an example of overgeneralization, a student who believes that good models show all the steps in the process might prefer a model of photosynthesis with 5 steps over one with 3 steps on the grounds that the 5-step model shows more steps – even though the two additional steps are not actually supported by any evidence. What this student fails to grasp is that some criteria take priority over other criteria. A prime solution to the problem of overgeneralization is to help students refine their general understanding of the *conditions* under which different criteria are applicable. In PRACCIS classes, teachers are encouraged to invite students to articulate conditions under which one might prefer a model with fewer steps over one with more steps. Consequently, students learn how to weigh competing criteria, and some of the conditions that govern which criteria take precedence in different situations. Thus, the problems of overgeneralization can be addressed in part by enabling students to develop an understanding of (still relatively general) conditions under which different criteria are to be applied.

Undergeneralization occurs when a student fails to apply a criterion when it is relevant. For example, a student may decide to adopt a diet based on a friend's anecdotal success while ignoring evidence about the health risks associated with this diet. Among several possible sources of undergeneralization, we would like to focus on one: Students may simply not believe that the epistemic criteria in question are valid. To facilitate students' acceptance of the criteria as valuable, we encourage teachers to hold meta-criteria discussions incorporating justifications for *why* different criteria should be adopted (or not adopted). For example, by discussing *why* one should prefer models that fit the evidence, students can come to appreciate the justifications for the use of fit-with-evidence criterion.

In short, the limitations of general knowledge of epistemic criteria can be addressed in part by helping students develop more nuanced (*conditionalized* and *justified*) but still relatively general epistemic criteria. But still, we argue below, there are limitations even to these more nuanced criteria.

### **The Limitations of Even Conditionalized and Justified Epistemic Criteria**

Using the case of epistemic criteria, we have argued that general knowledge can be made more useful if it is conditionalized and justified. But, even if students learn more conditionalized and justified criteria, we argue that they will still be limited in their ability to apply these criteria to new domains. Our analysis identifies three specific limitations. First is the problem of *failure to identify referents*. A student with a nuanced understanding of evidential criteria may nonetheless find it impossible to identify what the evidence is in an unfamiliar domain--that is, to pick out the referents of good evidence in the real world. For example, a student reading about whether vaccines cause autism may be committed to choosing the theory best supported by the good evidence, yet be simply unable to identify good evidence due to poor understanding of medical research design. Second, and a more serious difficulty, arises from *referent misidentification*. A person applying evidentiary criteria would erroneously identify something as evidence when it is not. For example, a student studying global warming could fastidiously examine evidence of local weather conditions while failing to appreciate that this does not, by itself, count as evidence for long-term climate patterns. Third, and a particularly insidious problem, is *narrow knowledge*. Even if a student were competent in evaluating a piece of scientific evidence about the safety of vaccinations, the student lacks the experts' much more extensive knowledge of the broader evidence base on the topic. Experts in scientific fields are aware of a vast array of evidence that laypeople are not aware of, and this gap cannot be redressed without becoming an expert oneself.

Unlike the under- and overgeneralization problems there is no solution to these three problems except deeper domain knowledge. Even a person with extensive general knowledge will suffer from *narrow knowledge* unless she herself gains true expertise in the field. As many have pointed out in recent years, ultimately in areas of non-expertise, one must trust experts (e.g., Bromme et al., 2009). All of this is not to say, however, that the general knowledge is not useful. A student who has a nuanced appreciation of evidentiary fit as an epistemic criterion will know at least two things that the student without this general knowledge will not know. First, the student with general knowledge of epistemic criteria will know a useful range of questions to ask experts in the field. The student could ask about types of evidence available as well as sample size and control groups. Further, the person who has learned epistemic criteria will have command of some of the discourse practices of the expert community and will have a greater capacity to seek out information.

# **Evidence against Using Domain-General Examples to Teach a Domain-General Concept/Skill**

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The long term goal of instruction is to have students acquire knowledge and skills that are widely applicable, rather than tied to the specific context in which they were acquired. However, the question about whether the initial learning materials and contexts should be domain-general or domain-specific, remains controversial. A substantial body of research has found that embedding domain-specific information in instructional examples helps learners understand these examples (e.g., Goldstone & Son, 2005; Goldstone & Sakamoto, 2003; Koedinger & Nathan, 2004; Kaminski, Sloutsky, & Heckler, 2006; Witzel, Mercer, & Miller, 2003). However, some research suggests that using domain-specific materials inhibits transfer to novel contexts (Kaminski et al., 2006; 2008; 2013; Bassok & Holyoak, 1989; Goldstone & Sakamoto, 2003). Consistent with these findings, which suggest that domain-specific information supports initial learning and abstracted representations better support transfer to new domains, Goldstone and Son (2005) found that transfer performance among college undergraduates was greatest when the domain-specific information was “faded” during the training task (or present initially in the training session and “removed” later). We describe a study that investigated the effect of fading domain-specific information in instructional examples on transfer outcomes.

## **Method**

The domain-general concept/skill taught was simple experimental design. In the sections of instruction discussing domain-specific examples of experimental set-ups, specific variables and values were used in examples and in instructional explanations (e.g., “to determine whether the slope of the ramp affects how far balls roll, one should make one ramp steep and the other not steep and make the surface, starting position, and type of ball the same for the two ramps”). In the sections of instruction discussing domain-general examples, experimental variables and their respective values were described generically as “Variable A/B/C” and their levels only given as “the same” or “different” across conditions. Instructional explanations were more abstract (e.g., “to determine whether Variable X affects the result, one should make Variable X different across conditions and all other variables the same across conditions”).

6<sup>th</sup>- and 7<sup>th</sup>-grade students at a suburban middle school worked individually on computers learning how to design unconfounded experiments in one of three conditions. In all conditions, students evaluated a series of three experiments. After each evaluation, students received feedback on their evaluations followed by explanations for why the experiments were or were not “good experiments.” All instructional experiments were represented in tabular/text form (i.e., no pictures of the set-ups were present). In the “all-concrete” condition, students evaluated three experiments using ramps; each experiment included specific variables (e.g., slope) and corresponding values (e.g., steep/not steep). In the “concrete fading” condition, students first evaluated a concretely-represented ramps experiment (as in the first condition), then an intermediately concrete experiment (with specific ramps variables but unspecified values represented only as “the same” or “different” across conditions). In the final, “abstract fading” condition, the experimental presentation order was reversed from the concrete-fading condition. The next day, all students completed a test assessing their ability to transfer their knowledge to domains other than ramps.

## **Results**

Results suggest that the benefits of incorporating this additional information (i.e., the specific experimental variables and their values) throughout instruction were greater for younger and lower-ability students: The transfer performance of younger students (6<sup>th</sup>-graders) and lower-ability 7<sup>th</sup>-graders was generally best in the all-concrete condition. However, higher-ability 7<sup>th</sup>-graders performed equally in the all-concrete and concrete-fading conditions and better than students in the abstract-fading condition. Across the board, students performed poorly in the abstract-fading condition, suggesting that supporting domain-specific information is in general critical in the early stages of learning. A post-hoc analysis suggested that the additional concrete features supported students’ ability to identify experimental confounds, or variables that—because they were contrasted across conditions – may have affected the outcome.

## **Discussion**

Our results are counter to Goldstone and Son’s (2005) finding that fading domain-specific information during training led to better performance of college undergraduates on novel transfer problems. Instead, we found that the transfer of domain-general experimental design skills was best when domain-specific examples were included throughout instruction. However, among the older students, the concrete-fading and all-concrete conditions performed similarly on the transfer task. One possible reason for these differences is that the continued exposure to domain-specific examples was necessary to support younger and lower-ability students’ understanding of the impact of confounded variables, a concept that was not as effectively conveyed in the

abstracted form of the instruction. These results suggest the possibility that—at least when additional domain-specific information directly supports learners' understanding of the instructional topic—instructional materials and contexts that are *not* domain general may be most effective for teaching younger and lower-ability students a domain-general concept/skill. However, because this study included only minimal additional domain-specific information, further research is necessary to determine the optimal amount of information to support transfer as well as how it interacts with student characteristics such as prior knowledge and general ability.

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## Acknowledgments

Contribution by Chinn, et al.: This material is based upon work supported by the National Science Foundation under Grant No. 9875485. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Contribution by Wecker et al.: This contribution was supported in the IPID program of the German Academic Exchange Service (DAAD).

# Science Sims and Games: Best Design Practices and Fave Flops

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**Abstract:** We represent a variety of educators and designers who have in common a deep concern about the quality of STEM learning and how new media tools are designed and used. These tools run the range of interactive simulations to embodied games with full arc narratives. We believe there is not one correct way to instruct in science using new media. For example - some formats (e.g., whiteboard vs. tablet) may be better for some learners (low vs. high prior knowledge) in some situations (single learner vs. small group) on some content (abstract vs. concrete). Our goal is to highlight some of the games and simulations we have designed and disseminated, and to explore their strengths and weaknesses. Each participant will present an original work, show a demo, present data on efficacy, and finally share anecdotes about what was done well and what could have been improved.

## Embodied Science Education: Design Principles and Rolling It Out

Mina C. Johnson-Glenberg and Caroline Savio-Ramos

The Embodied Games for Learning (EGL) lab creates learning scenarios. These are interactive motion capture games that are designed to increase K-12 student learning. Along the way we have learned several extremely valuable lessons about design and real world dissemination. We begin with our game design precepts, move to results, and then end with several lessons learned – many of them the hard way.

The EGL lab is somewhat different from other learning game design labs is that we integrate gesture and novel motion capture technologies (for example, the Microsoft *Kinect* sensor and Leap Motion) where they are most efficacious for learning. The affordances of the myriad, rapidly-evolving technologies are exciting but changing so quickly that no one can remain an expert in the most innovative tech for long. The technology also has effect on our STEM topic choices. We would rather create a levers curriculum than focus solely on polynomial equations, because we can readily envision how the arm can act (and be tracked) as a lever. When we design we follow these precepts:

- Make it *embodied* – with as much gestural congruency as possible. This means that the gesture matches the content (e.g., spinning your arm in a circle to the right makes the virtual gear rotate in a clockwise revolution).
- *Socio-collaborative-* build in discourse opportunity and space for reflection, require observing students to do meaningful tasks
- Make it *generative* – constructive and active
- Wrap in *narrative* – make them care
- Give *immediate performance feedback*
- Level up in *cycle of expertise* - AI adaptive if possible (We like to use machine scoring algorithms as well.)
- Try to include *user-created content* - Students should be producers, not just consumers of technology. It takes time and more programming funds to build user-friendly editors that allow users to input content, but it greatly pays off in increases in motivation and “stickiness”.

Our first embodied learning environment was a mixed reality platform (Milgram & Kishino, 1994) called *SMALLab* (Situated Multimedia Learning Lab) (D. Birchfield, Johnson-Glenberg, Savvides, Megowan-Romanowicz, & Uysal, 2010). This system used 12 infrared motion-tracking cameras either mounted in a ceiling or on a trussing system. The cameras record where in 3D space a student is holding a rigid-body trackable object (the wand). The floor space is 15 x 15 feet and so it feels VERY immersive to the student in the space (generally two at a time). By dipping the wand below a certain level on the Z axis, a virtual object projected on the floor could be “grabbed” by the wand and moved to another location (like a typical “drag and drop” interaction). Two notable differences between this platform and a traditional desktop one are that students can 1) locomote through the immersive environment and be tracked, and 2) the affordance of the open environment that an entire class can sit around the perimeter and partake in the lesson via observational learning. (See why locomotion is important and a Taxonomy of Embodiment in Education in (M. C. Johnson-Glenberg, Birchfield, Tolentino, & Koziupa, 2014).

Observing students who are on the perimeter of the *SMALLab* active space are encouraged to collaborate via discussion and whiteboard activities while the two active students in the *SMALLab* space are interacting with the system. The effectiveness of this platform has been demonstrated in several content domains include language arts (Hatton, Birchfield, & Megowan-Romanowicz, 2008), STEM- physics (M.C. Johnson-Glenberg, Birchfield, Savvides, & Megowan-Romanowicz, 2011); (Tolentino et al., 2009); geology (David Birchfield et al., 2009), and Disease Transmission (M. C. Johnson-Glenberg et al., 2014) . We found that an entire classroom (up to 30 students) would remain engaged for an entire 50 minute lesson with this large scale platform. Part of that may be because the observing students were often given roles – to be recorders of what was happening or to write out predictions. In addition, there is an intense performative nature to the situation. Every student knows his/her turn will eventually arrive and the students do not want to fail in front of their peers. We try to make the tasks low stakes and game-like, but we believe this expectation of performance drives a fair share of the sustained attention. All of our teachers were delighted with this aspect of the system.

## Switching Platforms



Figure 1. *Alien Health* game using *Kinect* and vertical projection

The *SMALLab* system was a powerful learning platform, but it was costly and not very mobile, so we started designing for the skeletal tracking sensor called Microsoft *Kinect*. We were able to keep the performative nature intact as students must still come to the front of the room and perform in front of an Interactive Whiteboard (IWB). However, now that the virtual surface is vertical and smaller (typically an IWB has a 7 foot diagonal) we see changes in the learning dynamics. With this transition we noticed that whole classroom engagement fell off after a period of time. We describe the Alien Health Game as an example. This is an embodied exergame designed to teach 4<sup>th</sup> through 12<sup>th</sup> grade students about nutrition and several USDA *My Plate* guidelines. A submitted study assessed efficacy and accessible (M. C. Johnson-Glenberg & Hekler, submitted) 2013 - in the *SMALLab* space. We observed full engagement for the one hour class for 4th graders. However, when the platform was altered to the *Kinect* (vertical and smaller) and we tested it on 20 6<sup>th</sup> and 7<sup>th</sup> graders, we noted that attention was not highly maintained after fifteen minutes (or after the first three dyads played).

## The Kinect Pilot

Participants were randomly assigned to either the Alien Health game or a treated control condition that also performed in front of a whiteboard. Players learned about the amount of nutrients and optimizers in common food items and practiced making rapid food choices while engaging in short cardio exercises. All players engaged in “front of the class” performative activities at the IWB. The alien would get progressively more fatigued if fed the poorer food choice. See Figure 1. The match pair in this image includes a bran muffin versus a cupcake. The Alien Health group experienced the game narrative of feeding the alien and the *Kinect* sensor gave feedback on quality of cardio exercise. The control group experienced the same performative food choices at the IWB, but did not perform the cardio exercises. Significant learning gains were seen in both groups on the

immediate posttest. The Effect Sizes from pretest to two week follow-up were .83 for control and 1.14 for the experimental group- significant but not differentially so. However, we did see a crossover interaction from immediate posttest to follow-up that approached significance,  $F_{(19)} = 3.96, p < .058$ , that favored the experimental group. Thus, students retained more knowledge after doing the exercises on a two week follow-up. Several of our studies have demonstrated gains are not always evident on immediate posttests but become evident at follow-up – and at that follow-up point the gains favor the embodied learning group.

In sum, participants who use more bodily gestures appear to show better retention of knowledge after a period of “consolidation”. We encourage our colleagues to include follow-up tests when possible. We will also discuss why a memory trace may be stronger when content is learned via embodiment and the challenges of delivering professional development to the teacher community using new technologies. We look forward to a participatory section at the end of all presentations where we (Drs. Johnson-Glenberg and Lindgren) will collate ideas from members of the audience on best design and implementation practices for simulations and games for learning. The goal is to then share those principles with a broader community.

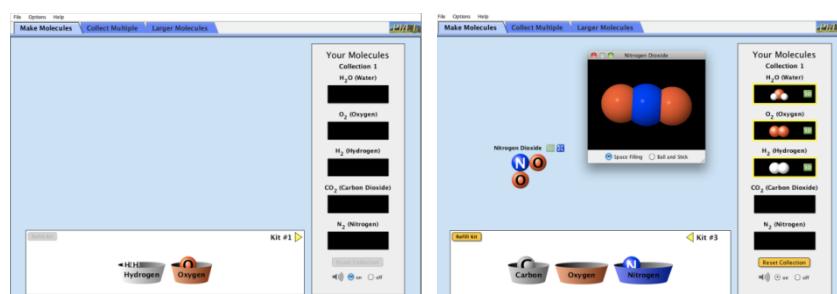
## Blending Implicit Scaffolding and Games in PhET Interactive Simulations

Katherine K. Perkins and Emily B. Moore

Since 2002, the PhET Interactive Simulations project at University of Colorado Boulder has been engaged in research around effective simulation (sim) design strategies for supporting inquiry-based learning of science. Our design approaches and strategies aim to simultaneously support multiple educational goals. In addition to developing knowledge of and engaging students in science content, process, and practices (NGSS Lead States, 2013), we seek to attend to student motivation and ownership by creating environments where students experience control and choice over the learning experience, and perceive the experience as challenging but interesting and attainable (Pintrich, 2003).

*Implicit scaffolding* in interactive simulations has emerged as a powerful design approach for achieving these multiple goals (Moore, Herzog, & Perkins, 2013; Podolefsky, Moore, & Perkins, Submitted) – drawing on the education research literature (e.g., Bransford et al., 2000; Norman, 2002; Mayer, 2009) and our experience of designing over 100 interactive simulations (e.g., Podolefsky et al., 2010). Implicit scaffolding employs affordances, constraints, cueing, and feedback in order to frame and scaffold student exploration without explicit guidance. Successful designs leverage what students know (e.g. buckets hold things, scissors cut), cue focus on important factors through intuitive designs (e.g. cuing attention to chemical formulas through molecule collection boxes or to key parameters by using sliders), tap into natural curiosities (e.g. spark “what if?” or “why?” questions), and support building of knowledge (e.g. using tabs to scaffold complexity). When successful, students perceive the sims as engaging, open exploration spaces, while the implicit scaffolding provides cuing and guidance so students are inclined to interact with the sim in productive ways.

In this presentation, we will focus on PhET simulations which utilize both implicit scaffolding and either implicit or explicit games to create a learning environment. The games – while relatively simple – are designed to target development of core concepts and learning goals and to enable users to test and revise their understanding. Interviews and classroom testing look for evidence that the challenges in the game support student sense-making around and productive progress towards learning of core concepts – as opposed to learning to “game the system” without progress towards learning the content. If the latter is found, the game is revised or removed. Through the overall simulation design and use of multiple screens, students retain choice and control over their learning experience – freely moving between exploring simulation features and screens, and working on solving game challenges.



**Figure 2.** Screenshot of the *Build a Molecule* simulation showing implicit game (left) on startup and (right) during use – with Jmol window open showing a three-dimensional molecule representation.

We provide evidence of the effectiveness of these design approaches using data from student interviews and classroom use of the *Build a Molecule* simulation (Figure 2). The simulation goals are to support students in integrating pictorial and symbolic chemical representations, and in interpreting and producing chemical formulas with coefficients and subscripts. In the classroom study, the simulation was used in an activity by three 5<sup>th</sup> grade classes, with a total of 64 students. Students were given pre, post and delayed post assessments. Significant increases – pre-post gains ranging from 23% to 78% – were found in the amount of correct responses to all assessment questions involving writing chemical formulas from molecule pictures or drawing molecules from chemical formulas.

## **“How Do I Move This?”: The Delicate Dance of Control Mechanisms in Embodied Science Learning Simulations**

Robb Lindgren

The emergence of computer interface devices that accept gross physical movement as input has facilitated a new paradigm of educational technologies where a learner can use their bodies as a vehicle for understanding novel concepts and giving access to transformative ideas. Computer-mediated simulations equipped with motion tracking technologies allow learners to interact with scientific and other phenomena in ways that may be more intuitive and expressive (Johnson-Glenberg, Birchfield, Tolentino, & Koziupa, 2013), and they have the potential to leverage body-based metaphors for developing complex understandings (Antle, Corness, & Droumeva, 2009; Lindgren & Moshell, 2011). Despite this potential, designing body-based interactions in digital environments that engender desired effects of insight and robust conceptual development is non-trivial. One issue is that the physical actions that a user is prompted to perform (e.g., using arms and hands to push a virtual button or move a virtual slider) may not be sufficiently commensurate with the learning goals of a simulation (Lindgren & Johnson-Glenberg, 2013; see also Segal (2011) for “gestural congruency”). Another issue is that body-based interfaces to simulations may offer insufficient or ambiguous control mechanisms that make it challenging for learners to map the activity of their body onto simulation events and outcomes. There is sometimes a tendency, for example, to “pack too much” into the translation of a single body action, which disrupts a learner’s ability to effectively utilize the interface metaphor. Here I discuss strategies and lessons learned for the design of control mechanisms for embodied science learning simulations.

Previous research suggests that students often struggle to acquire effective strategies for scientific experimentation such as adopting a control of variables strategy to isolate the effects of a specific parameter (e.g., Schauble, Glaser, Duschl, Schulze, & John, 1995). Typical science learning simulations do little to alleviate this struggle by frequently making multiple parameters available for simultaneous manipulation—picture the prototypical simulation as one with some phenomenon (e.g., shooting an object up in the air) depicted graphically and a series of slider bars and/or input boxes located off to the side. Simulations that take in gross motor movements have an analogous problem in that these actions operate in three dimensions and can consist of multiple temporal components, meaning that a single physical action such as waving one’s hand in the air has the ability to correspond to multiple simulation parameters. And even if the physical action corresponds to only one parameter in the simulation, it can be challenging and ultimately unsatisfying for a learner to discover that only one aspect of their physical act—side-to-side movement in the horizontal plane, for example—has a consequential effect on the simulation.

I observed these interface challenges firsthand as my research team was designing an immersive mixed reality floor-projection-based simulation of planetary astronomy that aimed to build middle school students’ intuitions about the physics of how objects move in space. The simulation was built around the metaphor of “learner as asteroid” where the user would utilize their body to set the asteroid into motion and then actively predict its subsequent trajectory based on the presence of gravitational forces (i.e., nearby planets). In the first iteration of the simulation learners launched the asteroid simply by walking off a virtual platform; the simulation registered the position and velocity of the learner at the point they crossed the “launch line.” From a technical standpoint this was a seamless interface mechanism because it allowed the simulation to transition from the parameter specification phase to running the simulation without interruption. From a learning perspective, however, the fact that all three pertinent launch parameters (horizontal position, angle, and speed) were being set simultaneously with one step across the line led to numerous instances of confusion about how to control the asteroid’s movement and what were the respective effects of the various parameters. As a result, there were no significant knowledge gains for the students using this version of the simulation compared to a control condition that used a desktop computer version of the same simulation. In a subsequent, second iteration of the simulation we changed the launching mechanism to a virtual spring in a tube instead of a platform (Figure 3 left). Using a scheme of arrows and highlighted “hot areas” learners were directed to use their bodies to set the three parameters sequentially. Learners caught on quickly to bodily conventions for setting the spring launcher and exhibited a greater awareness of how each parameter affected the asteroid trajectory. Most importantly, learning results from the study utilizing the second iteration control mechanisms showed a significant advantage for the

learners using the bodily controls compared to the desktop version (Lindgren, Tscholl, Johnson, Glasshof, & Moshell, 2014).



**Figure 3.** A participant using their body position to set the launch parameters via a virtual spring (left) and a participant using their body to control the frequency of a wave (right).

The emphasis on control mechanisms in science learning simulations has been extended into the design efforts of subsequent body-based simulations in other areas of science that will be demonstrated in the session. For example, in an immersive simulation of waves, rather than having participants replicate the literal movement of waves across space, they are instead being prompted to enact individual components of wave behavior such as frequency; learners use their bodies to anticipate the number of cycles per a given unit of time (Figure 3 right). The possibilities for embodied interactions for generating powerful learning experiences in science is expansive, but successful body-based interfaces will require special attention to mechanisms of control, and taking great care to convey to a learner how their gross movements translate to simulation parameters and ultimately to core science concepts.

## Evolving and Balancing Informal and Formal Representations

Douglas Clark, Corey Brady, Pratim Sengupta, Mario Martinez-Garza, Deanne Adams, Stephen Killingsworth, and Grant Van Eaton

School science, with its traditional focus on explicit formalized knowledge structures and learning but not *applying* factual knowledge, frequently does not address tacit understandings, and thus does not support students in revising their intuitive misconceptions. Interestingly, well-designed digital games are exceptionally successful at helping learners build accurate intuitive understandings of the concepts at the heart of the games due to the situated and enacted nature of good games (e.g., Gee, 2007). Most commercial games fall short as platforms for learning because they do not help people articulate and connect their evolving intuitive understandings to more explicit formalized structures that would support transfer of knowledge to new contexts (e.g., Masson, Bub, & Lalonde, 2010). Our thinking about bridging these two approaches parallels Vygotsky's (1978) thinking about using everyday ideas to bootstrap formal ideas.



**Figure 4.** Surge Classic.

The granularity of the focal representations in a game, however, involves a careful balancing act to support this bootstrapping. Figures 4 and 5 show the progression of representations across our grants. Our original NSF SURGE grant included explorations of a relatively “realistic” 3D representation. Players enjoyed the visual perspective, but the 3D representation and disconnect from formal representations made bridging intuitive and formal knowledge difficult (Clark et al., 2011).

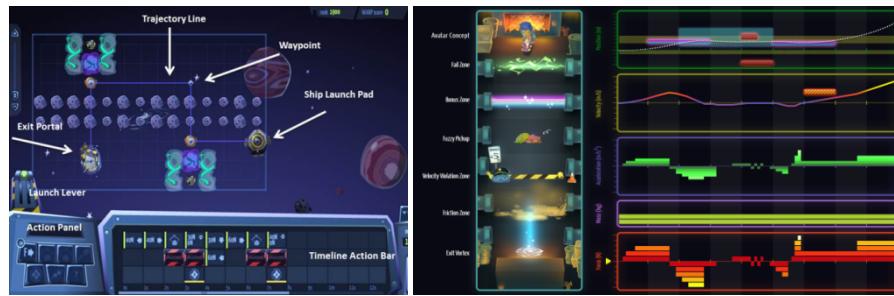


Figure 5. Surge 2 Fuzzy Chronicles (left) and SURGE 3 Away Missions (right).

Our subsequent DOE EPIGAME grant focuses on a 2D representation that integrates formal representations including dot traces, time lines, force magnitudes, and vector representations. Krinks, Sengupta, and Clark (submitted) found that this type of structure supports students in developing intuitive understanding as they shift in terms of the p-prims (diSessa, 1988, 1993) they leverage in their explanations, but Van Eaton, Clark, and Beutel (2013) have found that teachers and students connect their intuitive understanding to formal understanding in ways that support their initial misconceptions about the formal understanding. To address these challenges, our current research on this project focuses on leveraging self-explanation (Clark & Martinez-Garza, 2012; Adams & Clark, submitted) and integrated graphing activities (Sengupta et al., 2013).

Our NSF EGAME grant currently includes an exploratory focus on a highly schematized 1D representation of motion directly and tightly integrated and controlled through formal disciplinary graphical representations. This approach builds on a long history of having students match motion with graphs, control motion with graphs, or create graphs through motion with motion sensors. The most detailed work to date in this area was conducted as part of the SimCalc projects, beginning with MathCars (Kaput, 1994) and later MathWorlds (Roschelle & Kaput, 1996; Hegedus & Roschelle, 2013). SURGE1D extends SimCalc's use of Cartesian graphs as control structures that have "representational expressivity," (Hegedus & Moreno-Armella, 2009) in two critical ways. First, it uses the Cartesian space as a means for communicating critical game information to the player. For instance, the SURGE1D position graph holds forecasts about regions in the game-world that will be affected by electrical storms, as well as about locations where rewards or allies will appear to rendezvous with Surge. The velocity and acceleration graphs likewise indicate constraints on game-play, such as maximum or minimum speeds and maximum accelerations, each of which can be tied to narrative elements in game scenarios. SURGE1D also extends the expressivity of Cartesian representations by introducing the notion of a moving frame of reference. Both the challenges and the benefits to learners of representing relative motion have been recognized by researchers (Radford, 2009), and the importance of the selection of a reference frame is fundamental to the learning and practice of physics. In SURGE1D, the "camera" can be placed at any fixed location in the game-world, and it can also be mounted on a non-player character that moves at a constant velocity. The resulting transformations of graphical space offer opportunities for exploring narratives that involve making sense of other perspectives on the game-world.

Essentially, while our initial approach focused more on layering formal representations over informal representations, we are now exploring approaches that layer informal representations over formal representations while organizing gameplay explicitly and formally around navigating and coordinating across representations. Whereas SimCalc focuses on manipulating formal representations to achieve goals in the informal representation, we are attempting to extend SimCalc approaches by (a) integrating the goals directly into the formal representations in a way that projects onto the informal representations and (b) supporting the integration through advanced self-explanation functionality and representation decomposition.

## Methods for Supporting Professional Practice and Video Game Based Research

Matthew Gaydos, Amanda Barany, and Kurt Squire

### Effectiveness and Support

One of the most difficult challenges that educational technologies have faced has not been in the development of successful learning interventions, but in moving such interventions from the laboratory to the classroom, especially at scale (Cohen & Ball, 2001; Gomez, Gomez, & Gifford, 2010). Supporting the development and use of educational technologies means establishing teacher buy-in and ownership over the curriculum (Cohen & Ball, 2001; Gomez et al., 2010; Kwon, Wardrip, & Gomez, 2008). Educational video games similarly, require that researcher and developer designs be coordinated with teacher and administrator support. That is, in order

for games to be effectively and sustainably used in formal education settings, they must not only be content-laden and effective, but supported by local agents – those who will utilize them.

In this presentation, we summarize findings from two case studies conducted as a part of an on-going design-based research project centered on the educational video game *Citizen Science*. In each case, *Citizen Science* was used in authentic classroom settings. Its use was observed, documented and analyzed in order to examine teacher-designed curricula that 1) suggest modifications for future game designs and 2) suggest obstacles that may need to be addressed in similar game-based contexts.

### The game *Citizen Science*

*Citizen Science* is an action/adventure role-playing game designed to teach students civic-science literacy as related to lake ecology. In game, players engage in dialogues with non-player characters (NPCs) that represent stakeholder groups, collecting evidence in order to argue with NPCs and advance the game's narrative. The game is setting-specific, as players travel back and forth through time in Madison, WI, in order to convince local non-player characters to change their minds about how they use the local lakes. The goal of the game is to change the conditions of a local natural resource, Lake Mendota, especially so that the lake does not become hyper-eutrophic. If the lake were to become hyper-eutrophic, negative effects on the community could include fish die-offs because of decreased oxygen levels, unpleasant smells especially around the shoreline, increased toxic blue-green algae blooms, and an unattractive, murky aesthetic. Using elements typically found in commercial adventure video games including character, fantasy, humor, and strong role induction, *Citizen Science* is designed to provide students with an engaging and positive game-based experience, information about lake science content related to taking civic action within the local community, and the willingness to take action to improve the health of local lakes.

With regards to its intended use, *Citizen Science* was designed to be integrated into already-existing educational contexts, supported through teacher-developed curriculum. Within a classroom context and with the help of a teacher, the game's content could be reviewed, explained, and connected to its accompanying curriculum. This curriculum, in turn, can vary widely depending on the teacher's particular needs or educational goals. In the two cases that follow, we briefly describe the context and the *petite generalizations* (Stake, 1995) that characterize the game's relationship with established curricula.

### Two Cases of *Citizen Science* Use in Classrooms

In the first case, seven middle school students played *Citizen Science* as a part of a three-day science curriculum at a private school for the gifted and talented. Student learning was measured using an ad hoc multiple-choice questionnaire that covered game-related content and was administered at the beginning and end of the intervention. Students' scores on these tests showed improvement, increasing on average by 26% ( $SD = 16\%$ ) from pre- to post-test. The teacher and students' video and audio-recordings were reviewed and selectively transcribed for activities and dialogues in which the students and teachers were interacting with or explicitly referring to the game. During the intervention, students played the game during the first two days of class. On the third day, students and their teachers visited a local lake, where they made general observations of the lake's ecosystem, took water samples that were later examined under microscopes, and discussed local lake issues and ecology concepts with each other and with their teachers. Throughout the field trip, the teachers explained ecology concepts in terms of students' prior experiences, including previous classes they had taken, course material they had covered, and *Citizen Science* game play. For example, the teacher explicitly asked students to connect the scientific measurement practices that they conducted during the field trip to the parallel practices simulated within the game.

In the second case, 75 seventh grade students in a public middle school Life Science classroom played *Citizen Science* over the course of two days as the lake ecology portion of a five-week ecology unit. Student learning was measured by completion of an online worksheet in which students practiced organizing and creating evidence-based arguments using content from the game (results being analyzed now). Students also demonstrated their use of evidence-based argumentation in final projects. During the two-day curriculum, the teacher used note cards as a tool to mediate the intersecting needs of the school administration and the game-based curriculum. At the end of each class, the teacher asked students to briefly hand-write "one thing that they learned and one question they had" as a result of game play. In so doing, the teacher designed a simple tool that functioned as a formative assessment that could be referenced in class. E.g., the teacher referenced the note cards at the start of the second day of the curriculum, using student responses to prompt a discussion about blue-green algae. Because some students had incorrectly written that all algae could be fatal, the teacher wanted to clarify that only particular types produced toxins. These note cards thus served a dual function that we will explore in the talk.

## Discussion

Together, these cases highlight the importance of providing support for educational games in terms of their integration into curriculum with respect to content, and their integration into practice with respect to local constraints. In the first case, the teachers' practices suggest a need for support that helps draw connections between material referenced within the game to activities within the classroom. The note cards used in the second case highlight the need to develop assessments that can be used to meet content-based and institutional constraints. Similar to Hoadley's use of design narratives (2004) to promote understanding and ultimately reliability within messy, authentic contexts, video game based learning would benefit from techniques that encourage sharing game-specific educational practices. Our hope is that by presenting these cases of *Citizen Science* use within classrooms, we might prompt a discussion of how such sharing can be better promoted, particularly with regards to game design and educator practice.

## Exploring the Particulate Nature of Matter in a Constructionist Video Game

Nathan Holbert

Many video games include rich science phenomena and principles that players frequently encounter during play making them potentially powerful spaces for STEM learning. Designers interested in the educational potential of video games often attempt to create new games that both enhance the science phenomena commonly embedded in games as well as provide carefully orchestrate interactions that ensure players encounter the targeted phenomena. While many educational games have been shown to produce in players learning gains on measures that directly align with in-game action and mechanics, these same games often fail to show player improvement on *distal* problems (Clark & Martinez-Garza, 2012). This result suggests that while players may be gaining expertise with the game, they are not achieving a deep understanding of the concepts that underlie game mechanics.

Rather than design scripted experiences that ensure players confront targeted phenomena, I have explored game designs that privilege freedom and exploration. Borrowing heavily from the constructionist design paradigm which has been shown to be a powerful means of facilitating deep exploration of STEM concepts (Papert & Harel, 1991; Papert, 1980), these games engage players in the building of personally meaningful artifacts to overcome obstacles and challenges met in the course of more traditional genre gameplay. *Particles!* (Holbert & Wilensky, 2012), is a platformer game that encourages players to explore how the physical properties of matter emerge from the arrangement of molecular-level particles.

### Particles! Description

*Particles!* was designed to have the look and feel of a platformer video game while including principles central to the constructionist design paradigm (Papert & Harel, 1991). As in most platformer games, players are tasked with moving through a level full of obstacles to reach a locational goal. However, in *Particles!* players modify the game level as they play through it by removing existing world blocks and adding new designed blocks. Players design these new blocks at the molecular level—by adding and removing bonds between atoms to create large and complex molecular structures (Figure 6 left). These player-designed structures then serve as a template for the many molecules that populate the larger block that will be added to the game world. When these new blocks are added, they have physical properties emergent from the player-designed structures (such as bounciness or slipperiness), which in turn provides new options for how the player might complete each game level (Figure 6 right). These acts of construction encourage players to engage deeply with the mechanics of the game as well as the scientific principles (bonding and molecular structures) that are infused in these mechanics gaining a sense of the role molecular structure plays in object properties.



**Figure 6.** Players add and remove bonds between atoms to create molecular structures in the “atomizer” (left). These player-designed structures result in new emergent properties for blocks added into the game world (right).

In addition to including meaningful opportunities for construction, the atoms and bonds central to block building in *Particles!* visually and epistemologically align with the ball-and-stick model—an important representation used in the formal practice of chemistry. This visual similarity, and the alignment between the meaning and use of the representation in-game and in the formal domain, encourages players to see in-game block construction as a useful knowledge resource when thinking and reasoning outside of the game.

## Method and Data

Nine players, ages 11-14, were recruited from various non-school gaming clubs. Semi-structured clinical interviews were conducted with the participants 1-week before and after playing the prototype game. Interviews and game play occurred in informal settings and focused around the description of and explanations for the physical properties of Lego and Styrofoam blocks present during the interview. Interviews were videotaped, transcribed and analyzed for player invoked “concepts” using a coding scheme developed bottom-up from multiple passes of the data. In addition, participant drawings of the atoms that make up each interview block were analyzed for feature changes before and after playing the game.

## Results and Discussion

In this presentation I will show how participant explanations of the causes of material properties shifted after playing *Particles!* from focusing on the identity of the substance to more complex explanations of how the arrangement and structure of the particles that make up a substance might result in observed properties. In the pre-game all nine participants suggested the “identity” of the material (71 times) primarily determines an object’s properties while only five participants claimed properties are due to the arrangement and structure of the particles (24 times). In the post-game all nine participants were more likely to cite the structure and arrangement of block particles (57 times) as well as related constructs such as bonding as primarily responsible for observed properties. Eight participants also mentioned material identity (43 times). Furthermore, participant drawings of the particles that make up each interview block were significantly more likely to include images that showed many particles arranged in a specific pattern with many using the particular grid arrangement utilized in the game.

These findings indicate participants shifted from attributing object properties solely to the *identity* of atoms and elements that make up the object to both *identity and structure*. Furthermore, this shift seems to have been facilitated by participants’ experiences with game mechanics as in-game representations became central in participant explanations and drawings. The results suggest *Particles!* unique design may have provided players with a rich set of knowledge resources that they can freely access when thinking and reasoning in a variety of contexts. Furthermore, the success of *Particles!* offers important insight into possible design mechanics that can elicit deep learning in informal game play.

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# Teachers' Learning about Equitable Practice through Talk with Colleagues

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**Abstract:** Using insights from the learning sciences, the four papers in this symposium investigate the ways teachers' collegial talk contributes to their learning about equitable instruction. One pair of papers comes from primarily observational studies, investigating how everyday storytelling and facilitation stand to instantiate or challenge teachers' knowing about their diverse students and their instruction. The other pair of papers comes from design-experiments aiming to transform teacher knowledge. These contribute frameworks for understanding teacher learning through discourse. Together, the collection illuminates relationships between teachers' collegial talk and projects of instructional change.

## Learning to Teach Equitably

For education to fulfill its democratic function, teachers must effectively engage students from diverse backgrounds and support their learning and development. Such equitable teaching has been pursued by educators for decades and has yielded many well-articulated frameworks and practices. Nonetheless, we see evidence of persistent educational disenfranchisement of students, especially those living in poverty or coming from nondominant cultures.

Why is widespread implementation of equitable teaching so difficult? Scholars often point to longstanding traditions and institutional constraints in teaching (D. Cohen, 2011; Cuban, 1993). In this symposium, we take these conditions as a given but turn our focus onto issues of teacher learning. Frameworks from the learning sciences allow us to contextualize teacher learning within the school as a workplace, opening up new avenues for understanding the obstacles to and possibilities for making equitable teaching more commonplace in US classrooms.

To develop our perspective, we offer two observations about the challenges of teachers' learning equitable instructional practices. First, we note that many well-articulated equitable teaching approaches, such as culturally responsive teaching (Gay, 2010), tapping into children's funds of knowledge (Moll & Gonzalez, 1994), or complex instruction (E. Cohen, 1994) are characterized by teachers' responsiveness to the particularities of their students, making them highly situated forms of instruction. For instance, in Rosebery and colleagues' (2010) account of children learning about heat transfer, the students' key connection to ideas about insulation came from an unexpected fire drill in the dead of winter. After the children huddled to keep warm, the teachers leveraged this incident to build students' understanding. Likewise, Gutierrez and colleagues (1999) describe a teacher effectively making a "third space" in her classroom by hybridizing home and school discourses to facilitate students' understanding of science concepts. In both examples, teachers work with what students bring to the classroom to enrich their understandings of content. For teachers to competently respond in this way, they need to develop robust pedagogical judgment. In the moment-to-moment of instruction, pedagogical judgment presses on teachers to weigh social, individual, and content concerns, trying to optimize them in their decision-making with the dual goals of inclusion and learning (Lampert, 2001).

Our second observation is that widely available forms of pre-service and inservice education are highly acontextual, focusing on developing general knowledge for teaching that applies across teaching situations rather than cultivating the kind of judgment described in these prior examples. Zeichner (2010) has described typical teacher education as using a default *acquire-apply pedagogy*, where teachers "get" theory in courses and "apply" it in the field. In this approach, the underlying conception of professional knowledge can be likened to an appliance: instructional ideas can be plugged in and "work," regardless of the settings in which they operate. Thus, our primary mode of educating teachers is ill suited to developing the responsive practices equitable teaching demands.

If we have a mismatch between pedagogies and knowledge in teacher education, what are we, as a field, to do if we want to enfranchise more students in our schools? In this symposium, we aim to make progress on this question in two ways. First, we bring together papers from four different studies examining teachers' learning in contexts that are pressing for more equitable outcomes. We will identify the contributions of these analyses to our understanding of teachers' situative reasoning. All of the papers use teachers' talk as a primary data source and a window into sensemaking, identifying different ways collegial interactions contribute to

pedagogical reasoning. Two of the studies (Yoon, Kane) were primarily observational, looking at how teachers draw on workplace resources to understand issues of teaching. The second two studies (Bannister, van Es and Hand) took place within professional development projects aiming to develop teachers' knowledge of equitable practices. As a collection, these papers identify existing teacher discourses around issues of equity and point to possible avenues for shifting those discourses. By analyzing the affordances and obstacles for teachers' learning about equitable teaching, we can better understand how teachers come to develop these practices and support the democratic goals of public education.

### Prior Work: Colleagues as Resources for Teachers' Situative Sensemaking

As sociological studies of education have long shown, colleagues are one of the most salient resources for teachers' learning (Little, 1990; Siskin, 1994; Stodolsky & Grossman, 2000). What makes sense and seems "doable" in the classroom is, in part, a reflection of workplace norms, which get negotiated with other teachers. In fact, schools and departments that demonstrate more equitable student achievement have in common that teachers take collective responsibility for student learning, signaling the role of colleagues in equitable teaching (Bryk et al., 2002; V. Lee & Smith, 1996)

Using these insights as a point of departure, Ilana Horn, the organizer of this symposium, has spent over a decade researching teachers' collegial learning by examining pedagogical reasoning in teachers' conversations. Some key findings of this work are relevant to the implementation of equitable teaching, including:

1. Teachers' collegial conversations are *asynchronous* from the interactive work of instruction. When teachers talk about instruction, they typically do so prospectively (planning) or retrospectively (debriefing) (Hall & Horn, 2012; Horn, 2010; Horn & Kane, 2012).
2. The intersubjectivity achieved through collegial conversations is constrained by a dearth of professional language (Dreeben, 2005; Hall & Horn, 2012). Teachers fill this gap through *representations of teaching* (Horn, 2005; Little, 2003), such as artifacts of practice like textbooks or student work, or through conversational representations of classroom interactions.
3. Local teacher cultures promote *epistemic stances* on the work, which, in turn, support some framings of teaching problems over others. Together, epistemic stances and frames shape pedagogical reasoning and "common sense" teaching choices (Hall & Horn, 2012; Horn, 2007; Horn & Little 2010)

Together, these three findings provide a basis for understanding how collegial conversations operate as a resource for teachers' sensemaking about equitable teaching practices. At the very least, they point to the limited horizon of observation (Hutchins, 1995) on instruction available to teachers, which compounds the difficulties of sharing highly situative instructional practices. Adding to their limited learning affordances, collegial conversations often provides emotional support for teachers, but norms of privacy provide few means for pushing back on taken-as-shared ways of viewing pedagogical problems (Horn & Little, 2010; Little, 1990).

### Overview of Papers

These four papers deepen our understanding of how colleagues contribute to teachers' sensemaking about their work. The studies concern teachers in urban schools and raise questions about how teachers might come to teach more equitably in these settings. The distinctions among the studies are generative for discussion, as they each approach the issue of sensemaking with colleagues in different settings, at different grade levels, and using different grain sizes for analyses. At the same time, there is enough in common to support comparison: they all focus on discursive methods for understanding the contribution of colleagues to teachers' situated sensemaking. There is a balance in this collection between teachers' discourse as it typically unfolds to reinstate existing conceptions (Yoon, Kane) and discourse as it might be engineered to probe and extend to ways enrich them (Bannister, van Es and Hand).

As a whole, these studies help specify our understanding of teacher learning. Instead of viewing professional development as effective or ineffective, these analyses point to:

1. The interactional details that are consequential for learning (Yoon's critical discourse analysis of teachers' storytelling; Kane's analysis of expertise and facilitation; Bannister's frame analysis);
2. What learning might look like at the level of teachers' talk (Bannister's frame shifting; van Es & Hand's noticing)
3. How rich representations of practice stand to deepen the understandings of already accomplished teachers (van Es & Hand's video club).

The 90-minute symposium will consist of three 15-minute paper presentations, 15 minutes of commentary from our discussant, leaving 15 minutes for audience interaction.

# **Trading Stories: Middle-Class White Women Teachers and the Creation of Narratives about Students and Families in a Diverse Elementary School**

Irene Yoon, University of Utah

In the hallway, in the staff lounge, and in team meetings, teachers tell stories about their day and their students. Starting from this common occurrence, this paper examines collective storytelling in teacher communities in a racially and socioeconomically diverse elementary school that I call Fields Elementary.

The narrative progression of a group conversation has the potential to limit or stretch the boundaries of professional learning and the development of shared meaning. An *intersectionality perspective* on middle-class White womanhood affords the tools to interpret storytelling as the central vehicle for creating meaning in the teacher community in this paper.

In order to examine storytelling among a group of middle-class, White teachers at Fields Elementary, I ask: first, what are the narrative tropes that these middle-class White women teachers draw upon to create common language or understanding about what it means to teach at their school, and how does this narrative unfold? Second, in what ways does a normative middle-class White culture, specifically related to White womanhood, achieve ideological projects through the ways in which teachers participate in collective storytelling in professional communities? A critical discourse analysis provides insight into these questions.

## **Study Context**

The analysis and data presented in this paper come from a larger qualitative case study conducted using ethnographic data collection strategies for roughly five months. I immersed myself in Fields Elementary, a racially and ethnically diverse elementary school where approximately 40% of the students are English Learners. 73% of the students at Fields qualify for free and reduced-price lunch, and Fields also experiences approximately 50% student mobility each year. The Fields faculty is predominantly White and female, as well as middle-class.

Fields's teachers have structured opportunities to collaborate. The conversation that is the focus of this paper occurs in the second-grade teacher community. All teachers on the team are White, middle-class women with varying years of teaching experience. I was not a participant in the study; I interacted with teachers and students, but tried to be unobtrusive. In the paper I discuss my experiences as a middle-class Asian American woman researcher at Fields and as the only person of color in the room during this conversation.

## **Data Sources and Methods of Inquiry**

The teacher conversation presented in this paper comes from an audio recording of a formal teacher community meeting of the second-grade team at Fields Elementary, during which I also took scripted fieldnotes. These fieldnotes capture interactions nearly word-for-word and include gestural details filled-in immediately after observation (Emerson et al., 1995). Transcription of the conversation was first completed for verbal content, with a second round to notate non-verbal participation, such as pauses, sighs, laughter, or people talking over each other (Gee, 2005; Mazzei, 2004).

Discourse, as an instantiation of power, contributes to ideological projects, even if unintended or unconscious (Fairclough, 2001; Gee, 2005). The data were analyzed with a critical discourse analysis (CDA) of one team conversation. CDA examines language use to reveal and understand power dynamics, sociohistorical contexts, and meanings of speech and action in relation to social structure (Fairclough, 2001; Gee, 2005). In this analysis I adopt Fairclough's guidance that CDA include "*description* of text, *interpretation* of the relationship between text and interaction, and *explanation* of the relationship between interaction and social context" (p. 91).

## **Illustrative Findings about Teachers' Learning**

In this paper, storytelling is an activity of learning and socialization in professional communities. These narratives reflect the values and epistemology of the middle-class White women teachers—ways of seeing the world, and of defining knowledge and practice (Banks, 1998; Collins, 2009; Harding, 1993; Lightfoot, 1978). That is, race, social class, and gender are social locations that are both sources and production sites of meaning in this teacher community.

The conversation in this paper begins with sharing concerns related to students' histories of academic achievement, and many of the stories reflect some level of concern for students' physical, academic, and social-emotional wellbeing. However, stories also reproduce White, middle-class, deficit-based stereotypes about the morality and childrearing of people living in poverty and people of color. The discourse about parenting implies authority on motherhood among the middle-class White women teachers, particularly in the case of students' fathers, who behave like children themselves.

The collective narrative progression is central to this story; turn-taking, use of pronouns, and patterns of participation (including silence) contribute to meaning, information, and potential resources for the group's learning and identity (Duncan, 2004; Engeström, 1987; Horn, 2007; Mawhinney, 2008; Mazzei, 2008; Scott,

1991; Wenger, 1998). That is, these stories provide knowledge resources for middle-class, White women teachers to make generalized conclusions about what it means to teach at Fields. The knowledge resources are grounded in an ideological context of middle-class White womanhood. Four ideological projects accomplished by this example of trading stories include: 1) establishing social and moral distance; 2) constructing colorlessness as White middle-class morality; 3) decontextualizing institutional constraints on teaching at Fields Elementary; and 4) defining boundaries and identity of middle-class White womanhood.

### **Implications for Teachers' Learning**

Teachers, particularly elementary-level teachers who are with their students for a full day, know intimate details about their students' lives. Though trading stories is an informal part of professional collaboration, it comprises substantive moments for teacher learning and professionalization because the stories define the conditions and meaning of teachers' work and experiences in racialized, classed, and gendered terms. The kind of learning observed in this conversation is the generation of what Engeström (2007) calls "stabilization knowledge," or sharing information that secures, rather than expands, boundaries around how work and identity are envisioned.

The focus on the collective process of the storytelling is essential: the narratives and participation that reproduce middle-class White womanhood are constitutive elements of teacher learning. Resulting group dynamics shut down equity commitments, such that teachers as a group permit the painting of students and families in broad, demeaning strokes.

Finally, it is noted that the teachers at Fields do not address institutional constraints in their stories. Stories about individual merit and moral standing echo the liberalism of Whiteness and middle-class ethics that avoid institutional critique (S. Lee, 2005). In this way, a colorless middle-class White womanhood becomes the ideological and moral lens for professional learning, while the stories also reflexively create the teachers and their identities as moralized, racialized, gendered, and classed subjects. Challenging these everyday discourses has significance for teachers' identities, students' experiences, school-family relationships, and the larger goal of equitable education.

### **Facilitators' Expertise and Teachers' Opportunities for Learning**

Britnie Delinger Kane, Vanderbilt University

Because a host of studies note a relationship between teachers' collaborative work and school improvement (e.g., Langer, 2000; McLaughlin and Talbert, 2001), school districts are beginning to institute time for teachers to collaborate. Yet not all collaborative groups are equally generative for teachers' professional learning (Horn and Little, 2010), and the mechanisms for how teachers' collaboration can support school improvement are not well understood. Recognizing this problem, many schools have placed facilitators on collaborative teams (McLaughlin and Talbert, 2006; Parr and Timperley, 2010). However, this only pushes the issue downstream: facilitation itself is not well understood in relation to teachers' learning. It seems sensible, though, that the present of a more expert other might engender richer learning (Frank, Zhao & Borman, 2004). A more situated account of how expertise is accomplished and tapped into in interaction requires a closer look at this idea.

### **Research Question and Conceptual Frame**

This analysis focuses on how facilitators' expertise contributes to teachers' learning. Using sociocultural frameworks, I assume that facilitation is an interactional accomplishment in and through the resources that group members leverage in their collaborative work. In turn, the way facilitators accomplish this work will influence teachers' opportunities to learn about instruction. Representations of practice are one important resource for teachers' conversational learning, particularly when they highlight relationships among students, teaching, and content (Horn and Kane, 2012). To understand facilitators' role in supporting opportunities to learn, we can thus examine how their contributions develop the collective representation of practice. For instance, facilitators can ask probing questions and press for elaboration; alternatively, they can bypass such details and focus more on work completion in the group. One might expect facilitators' expertise to shape the nature of their press in conversation. In this paper, I explore this notion by investigating the relationship between expertise and teachers' opportunities to learn.

### **Study Context**

This analysis comes from a larger, two-year study in two urban school districts focusing on instructional improvement in middle school mathematics. Within that larger study, our research team has focused on a subset of schools that district and school personnel identified as sites of strong math teacher collaboration. The primary data for this analysis are a year's worth of interview and video data from teacher collaborative groups at Magnolia Middle School and Aspen Middle School, both located in the same district. Both schools were under strong pressure to meet state achievement benchmarks because of previous failure to do so. Institutional press for more equitable student outcomes often came up in teachers' conversations. The group at Aspen had no

sanctioned facilitator and no official leader. At Magnolia Middle, on the other hand, bureaucratically appointed facilitators were in abundance: an assistant principal (and former district-level math coach), a state department of education math coach, and a school-based math coach attended. Despite the differences in role, both facilitators had expertise in mathematics teaching according to our studies measures (described below).

### **Analytic Methods**

To understand the influence of expertise on facilitation and teachers' opportunities to learn, I use discourse and interaction analysis, as well as grounded theory, to analyze video and interview data (Strauss and Corbin, 1998). Specifically, since collaborative work is accomplished asynchronously from instruction, we know that representations of practice can be a resource for teachers' learning (Horn and Little, 2010; Little, 2003). Thus, I used grounded theory to code group members' contributions according to what aspects of practice they represented. I also coded questions according to the types of representations of practice they supported. This data set and method highlighted connections across facilitators' conversational processes, their pedagogical and mathematical expertise, and the larger contexts in which workgroups collaborated, in order to better understand teachers' opportunities for learning.

### **Findings**

Preliminary analyses reveal that, in collaborative workgroups, facilitators (emergent or appointed) and activity structures influence how teachers represent the classroom; these, in turn, affect teachers' opportunities to learn. At Aspen Middle School, the collaborative group did not have an appointed facilitator. However, an emergent facilitator emerged, and, according to our study's VHQMI and VSMC measures, she was, in fact, more expert than her colleagues. Perhaps more important than the study's measures, her colleagues ratified her as expert in their interaction. In this way, she emergently took on a facilitative role, as when she frequently asked, "What else do we need to do today?" If expertise alone led to rich learning opportunities, we might expect her presence to support conversations in this direction. However, conversations were also shaped by activity structures. At Aspen, the default collaborative activity *planning-as-pacing*. In this way, facilitation amounted to more than the presence of one expert; instead, it was accomplished through the emergent facilitator and the dominant activity structures, which, together, shaped teachers' opportunities to learn. The resulting conversations represented classroom practice in generic ways, focusing on classroom management and content coverage. On the whole, the richer representations of practice connecting particular details of students, content, and teaching did not emerge, thus providing teachers little traction on developing situated and responsive instruction.

By contrast, at Magnolia Middle, an official facilitator and a different dominant activity structure allowed richer representations of practice to emerge. For instance, a common activity was looking at student work. During these conversations, the group discussed how teachers might teach mathematical content in light of the group's analysis of these representations of practice. Combined with a highly expert coach, this activity structure supported rich representations of practice that honed in on the interactional details that would support responsive teaching. The facilitator frequently used her expertise to model discourse that directly reflected teacher-student interaction. Through such representation and analysis of classroom practice, the combination of activity and facilitator supported teachers' opportunities to learn about responsive instruction through their collaborative work.

### **Implications for Teachers' Learning**

Facilitating learning in teacher workgroups requires more than the presence of expertise within the group. The details of how that expertise manifests in interaction matters for teachers' opportunities to learn. Both Aspen and Magnolia had experts present in their groups. The dominant activities at each school were not inherently richer with learning opportunities: we have seen rich versions of planning and anemic instantiations of looking at student work. Instead, using these two case studies as exemplars, I argue that the activities get animated by how facilitators use their expertise. At Aspen, the activity structures and emergent facilitator led her to emphasize the management of group processes with an efficiency logic; their joint work got their planning done. At Magnolia, the activity structures and positioning of the coach led her to push on co-constructing specific representations of the classroom: she modeled the discursive practices teachers need in order to talk — and learn — about their practice in sophisticated ways. Opportunities for teachers' learning in workgroups, then, are not simply the consequence of the presence of expertise. The expertise stands to animate activities in ways that may or may not support resources for teachers' learning.

# Capturing Teachers' Learning Through Their Framing of a Struggling Student Problem

Nicole Bannister, Clemson University

## Research Question and Conceptual Frame

Empirical examples of teachers' development of equitable teaching practices within a community are few in number (Levine, 2010; Little, 2003). I take up this issue in my study by applying concepts from frame analysis (Goffman, 1974; Benford & Snow, 2000; Snow & Benford, 1988) to the trajectory of teachers' participation (Levine, 2010; Wenger, 1998) in a collaborative planning group. By tracing the evolution of teachers' frames over time, I analyze collective learning inside a teacher community. Specifically, I examine the shifts in teachers' framing of one pedagogical problem — the struggling student problem — over time.

## Study Context

This research took place in the context of a larger project, *Adaptive Professional Development for High School Mathematics Teachers*, a longitudinal design-experiment project. Clark High School, a diverse, large, urban comprehensive high school in a large school district in the northwestern US, was a partner in this work. During the 2004-2005 academic year, I followed the progress of the five-member *Freshman Team* at Clark, a collaborative planning team composed of all ninth-grade college preparatory mathematics teachers. With support from our project, teachers had a daily common planning period that they used to make sense of issues related to teaching and curriculum. In response to a student failure crisis the previous year, the teachers were, by their own volition, transitioning towards equitable teaching practices and newly implementing a rich curriculum.

## Analytic Methods

To document the teachers' collaborative talk, I collected 35 records of Freshman Team meetings over the course of the school year. The majority (31 out of 35) of these came from their weekly two-hour long meetings, the time when the teachers reported doing their deepest talking and thinking together. Of the 35 meeting records, 26 had fieldnote records and 32 meetings had audio records, with many meetings have both kinds of records available.

To understand how teachers' conversations changed as they worked toward more equitable teaching practices, I analyzed the meeting records. My analysis began with a data reduction, filtering the data set into *episodes of pedagogical reasoning* (EPRs) (Horn, 2005) related to the struggling student problem. Next, I selected representative episodes for more in-depth analysis. Finally, four episodes from October 2005, January 2006, March 2006, and May 2006 were selected for fine-grained re-transcription and analysis because they contained extended talk about the struggling student problem. When these episodes were taken together, they constituted a coherent narrative about the teachers' developing ideas about struggling students.

As a part of the close analysis, I coded these episodes for core framing tasks identified by Snow and Benford (1988) to help identify how teachers framed the struggling student problem in context of their equity-oriented reforms. Specifically, I looked for (a) *diagnostic frames* to understand how teachers conceptualized the struggling student problem; (b) *prognostic frames* to understand how teachers conceptualized interventions related to the struggling student problem; and (c) *motivational frames* to understand how teachers made a case for their framing.

## Findings

Over the course of the four episodes, the teachers' framing about *struggling students* shifted from fixed student characteristics to framings that provided the possibility of instructional response. For instance, in one of the early meetings, a teacher explains a struggling student this way:

I have the kid [Taylor] who is really flaky and doesn't know what's going on and is starting to annoy the rest of the group. So that's a really struggling kid and so they're starting to opt out.  
(Rose, 10/6/2005)

By focusing on Taylor's "flakiness," there is little the teacher can do instructionally to help the student be successful in her math class. Other similar language appeared in these early meetings, such as students "choosing to fail," another frame with very little instructional possibility.

In contrast, during the May meeting, frames emerged that focused more on classroom-based instructional responses, such as making exceptions for kids who understand the content despite failure:

He's not doing well now, but Taylor is so smart! And so here I am at the end of the year and I'm thinking, "Why would I put him back in Math 1?"... Because he obviously understands stuff. ... So I think there are some kids we need to look at a little differently ... there are some

kids maybe we shouldn't really keep back, 'cuz then we're really sentencing them to not ever be able...to come out of that. (Rose, 5/25/2006)

In this excerpt, we hear the same teacher (Rose) talking about the same student (Taylor) but in terms that recognize his competence ("so smart!"). The evolution of the teachers' framing reflects a growing collective awareness that achievement and ability are related but not synonymous. This is reflected throughout the data.

### **Implications for Teachers' Learning**

In terms of teachers' learning about equitable teaching, another aspect of the frame shift is worth noting. The earlier frames place the onus for achievement primarily on the students, while the latter provide teachers a means for action. As such, the teachers' frames became more nuanced in their representation of mathematical competence, disentangling issues of ability from school-savvy. By conceptualizing in their own talk ways to be responsive, the groundwork is laid for them to engage in equitable teaching practices. In this study, we found that teachers' frames shifted from less agentic to more agentic ways of understanding problems of practice as co-occurring with development of more equitable teaching practices.

This study contributes a way of operationalizing teachers' collective learning through its use of frame analysis, evidenced by how teachers negotiated and framed problems of practice over time. Looking at other teacher groups in the study, it seems that their changes in participation patterns also mirrored changes in their collective framing practices over time. Tracking frames offers a productive method for analyzing learning within teacher community.

## **Using Video to Collaboratively Examine Equitable Secondary Mathematics Teaching**

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### **Research Question and Conceptual Frame**

It is well documented that students who have experienced disparities in the opportunities afforded to them through the educational system consistently underperform in mathematics compared to their peers (Ball & Moses, 2009; NCES, 2005). Mathematics education research has made important progress in identifying instructional approaches that can strengthen learning opportunities for diverse student populations (see Nasir, Hand, & Taylor, 2008). Less is known, however, about how teachers come to engage in this complicated work *while* teaching.

Research on teacher noticing for ambitious mathematics teaching and learning has begun to articulate patterns in the ways that teachers attend to and reason about noteworthy features of mathematics classrooms (Sherin, Jacobs, & Philipp, 2010). This focus on teacher noticing is spurred by empirical research that demonstrates the link between teachers' ability to perceive and make sense of student thinking during instruction and their success in enacting cognitively demanding mathematics tasks during instruction (Erickson, 2011). We draw on the construct of teacher noticing to examine how teachers attend to and reason about classroom features that influence equitable learning for non-dominant groups. We also consider how a video club setting (Sherin, 2000) can become a context for teachers to learn about equitable mathematics teaching.

Our work is also informed by recent research that suggests that a shortcoming of research on teaching and teacher education is the lack of a shared language and knowledge base for describing and characterizing teaching practice (Grossman & McDonald, 2008; Hiebert, Gallimore, & Stigler, 2002). Progress has been made in the last decade to decompose ambitious pedagogy in several disciplines (Grossman et al., 2009; Thompson, Windschitl, & Braaten, 2013). This study contributes to this body of work by documenting similarities and differences in the ways that exceptional equitable mathematics teachers talk about their noticing in practice, with a particular focus on the features of classrooms that teachers attend to for achieving equity in their classrooms.

### **Study Context**

Six exceptional secondary mathematics teachers (from two large urban regions in the US) participated in the study over the course of one school year. District-level administrators and university-based teacher educators whose work focuses on improving mathematics teaching and learning with students from non-dominant backgrounds nominated these individuals because of their record of exceptional success teaching students from a range of ethnic, racial and linguistic backgrounds in their schools and districts. We conducted 10-15 observations in each teacher's classroom and videotaped a subset of these lessons. We also conducted a series of interviews where we asked the teachers to view selected segments from their own and other teachers' classrooms and to discuss what they noticed. We view their ways of noticing as a window into their dispositions as equitable mathematics teachers. Finally, we brought a subset of these teachers together in a video club

meeting to view selected segments from each other's teaching to document what they identify in each other's practices.

## Analytic Methods

For this paper, we analyze video data and field notes from the video club meeting to understand how this context can become a fruitful setting for teachers to develop more robust understandings of and a shared language for talking about equitable mathematics teaching practice.

Data analysis is qualitative in nature. To understand how the video club setting can become a context for teacher learning of equitable mathematics practice, we drew first on analyses of the individual teacher data. We reviewed the classroom observation and interview data to construct profiles of the three teachers who participated in the video club meeting. Our analysis was informed by Hand's (2012) framework that consists of three categories for the ways teachers support nondominant students in "taking up space" in inquiry-based classrooms: promoting dialogic space, blurring distinctions, and reframing the system. We used this analysis to inform our interpretation of the teachers' dispositions toward equitable mathematics teaching. We then viewed the video club meeting data and examined how the teachers' dispositions arose in their conversations, what language they used to describe and characterize what they noticed while viewing clips from each other's classrooms and how this context provided them opportunities to develop more robust visions of equitable mathematics teaching.

## Findings

Our first finding is that the three teachers have qualitatively different dispositions toward equitable mathematics teaching. One teachers' noticing can be characterized as mathematically oriented. He attended to students' mathematical thinking, their relationship to the mathematics and the ways they see themselves as successful mathematics learners. Another teacher's noticing can be described as student oriented. That is, he attended to their personal histories, lives and experiences and considered how these afforded or constrained their opportunities to learn in the classroom. And finally, the third teachers' noticing for equitable teaching can be categorized as developing student autonomy with mathematics. That is, he attended to ways students drew on another's thinking to develop their understandings and how the curriculum mediated their abilities to become autonomous math learners through collaborative work with each other.

Analysis of the video club meeting suggests that bringing teachers together can provide them with opportunities to develop more robust visions of equitable mathematics teaching. While all three teachers were considered exceptional equitable teachers, each exemplified different dimensions of the Hand (2012) framework. Thus, by viewing video of noticing for equitable learning as they arose in their teaching and then talking about together about their teaching, the teachers could come to see the multi-faceted nature of teaching practices for equitable learning. For example, when the group viewed clips from the "student oriented" teacher's classrooms, they saw him noticing disruptive behavior (e.g. student beat boxing in class) and then using that students' behavior to represent the mathematics they were learning, in this case rates of change. In this case, the teacher who is more "mathematically oriented" could see ways of *promoting dialogic space* and *reframing the classroom system* in ways that draw on students' ways of knowing and doing to create rich opportunities to access and learn the mathematics. Likewise, by watching videos from the other teachers' classrooms, this same teacher could begin to see ways that mathematically rich tasks can afford opportunities for deeper mathematical thinking and ways that teachers' interactions with students can *blur distinctions* to promote a range of participation structures and ways of representing mathematics.

## Implications for Teachers' Learning

This study suggests that video of teaching practice can provide not only insight into noticing equitable mathematics practice, but also ways that teachers can collaborate to learn about equitable teaching from one another. The findings of this work have implications for the design of professional development for supporting teachers in adopting more equitable dispositions to mathematics teaching and learning.

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# Motivating and Broadening Participation: Competitions, Contests, Challenges, and Circles for Supporting STEM Learning

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**Abstract.** National and local competitions have become popular venues to inspire students in K-16 to excel in math, science, engineering and computing. In recent years, online versions—such as the National STEM Video Game Design Challenge, Globaloria Awards, and Make-to-Learn Contest—have joined the portfolio. While competitions, contests, challenges, and circles are theoretically open to all, it is unclear to what extent they are not only motivating but are also broadening participation. The goal of this symposium is to better understand the dimensions of four different type of public events by reviewing (i) the design of the public event model, (ii) implementation of activities, and (iii) evaluation of participation and learning that amplify levels of youth participation in sharing design-based projects and increase opportunities for STEM learning for all.

## Overview

National and local competitions, such as Coding Wars, Google Science Competition, FIRST Robotics, Hackfest, Microsoft Imagine Cup—to name just a few of the ever-growing list—have become popular venues to highlight STEM accomplishments. While science fairs have a long tradition, starting with the first National Science Fair in Philadelphia in 1910, the number of these public competitive events has increased with recent efforts to inspire more students in K-16 to excel in math, science, engineering and computing. Online versions, such as the National STEM Video Game Design Challenge, Globaloria Awards, and Make-to-Learn Contest, have recently joined the portfolio. The goal of this symposium is to better understand the dimensions of these public events that amplify levels of youth participation in sharing design-based projects and increase opportunities for learning, online and offline.

Public STEM events, where students prepare, display, and share their artifacts, are widely believed to be a valuable learning experience (e.g., Abernathy & Vineyard, 2001; Grote, 1995; Yasar & Baker, 2003). Participation, often encouraged with support from teachers or parents, is highly correlated with later career choices in STEM majors (Forrester, 2010). At the same time, little is known about which aspects of these events motivate and sustain youth participation. Although actively engaging many youth, to date large-scale competitions have often encountered difficulties attracting and sustaining participation for students in groups traditionally under-represented in STEM careers (e.g., FIRST LEGO League, 2008-9; Greenfield, 1995). Research on achievement motivation suggests that an emphasis on performance and competition may be most motivating to students who already have high confidence in their ability (see review by Kaplan & Maehr, 2007).

While competitions, challenges, and contests are theoretically open to all, it is unclear to what extent they are not only motivating but are also broadening participation—an issue central to any STEM effort. One solution to address this concern has been to focus more on collaboration than on competition in the design of public events. For example, Rusk and colleagues (2008) present examples of organizing robotics exhibitions as an alternative to robotics competitions. Other solutions have been also used to leverage more collaborative models of production. For instance, in the *Connected Messages* project, conducted in the Summer 2013, hundreds of youth in public library branches designed and assembled message boxes that resulted in large public electronic displays. In this type of collaborative design event, rather than focusing on individual projects, the compilation of individual contributions completes the larger public design. Although differing in focus from competitions, exhibition-focused events still retain the idea of addressing an authentic audience (Magnifico,

2010), but they focus more on sharing of ideas than selecting a winner. While an array of approaches has emerged, to date little is understood about how to design features of public events, with or without competitive dimensions, to successfully engage broader participation of K-12 students as well as community members attending the events.

In this symposium, we bring together a first set of recent designs and studies that have implemented and evaluated different types of public competitive and collaborative events. Our goal is to understand how these events can be designed not only to support and motivate STEM learning but also increase diversity in participation. Online competitions such as the 2012 National STEM Video Game Design Challenge (<http://stemchallenge.org>) invite students to program games with STEM content and upload them, whereas the 2013 Make-to-Learn Youth Contest invites youth to share and explain physical rather than virtual designs for the possibility of garnering one of the prizes in different grade levels (<http://m2l.indiana.edu/make-to-learn-challenge/>). The 2011 Scratch Collab Challenge initiated collaborations between online members to program a Scratch project by using three different elements (<http://info.scratch.mit.edu/collabchallenge>). By contrast, the 2013 eCrafting Circles (<http://ecrafting.org>) include a hybrid of online calls that bring local community groups together in making physical artifacts for Halloween and end in local celebration of designs. Taken together, these four projects occupy different places on the continuum of collaboration versus competition, physical versus virtual designs, and individual versus collaborative productions, all of which can be key dimensions in the design of productive and meaningful STEM learning activities.

The chairs will introduce the theme and issues raised in symposium followed by 20 minute presentations that review the (i) the designs of each public event model, (ii) implementation of activities, and (iii) evaluation of participation and learning. Our discussant Alicia Magnifico, will review findings addressing issues of motivation and audience and discuss implications for future initiatives designed to increase and broaden youth participation in design-based STEM learning initiatives.

## **Feeding Competitive Streaks and Fostering Collaborative Determination: Grounding STEM Coursework in a National Video Game Challenge**

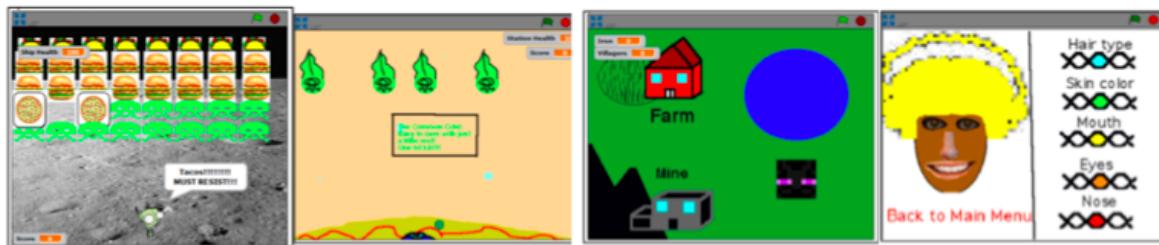
Quinn Burke, College of Charleston & Chad Mote, University of Pennsylvania

Recent reviews of making games for learning (Burke & Kafai, 2014; Hayes & Games, 2008) outline a number of reasons why making video games exemplifies important learning, including the potential to reinforce traditional academic subject learning (Dickey, 2005), to introduce children to computer programming (Kelleher & Pausch, 2005), and to expose children to more authentic audiences as producers and not merely consumers of digital media (Peppler & Kafai, 2010). Yet despite the merit of each of these goals individually, what is lacking is a particular “forum” within schools in which all these learning principles can collectively take root.

In this presentation, we argue the *game design competition* can represent such a forum. In an arena once solely occupied by robotics competitions, game design competitions have recently emerged on both local and national fronts as a way to attract a wider variety of children to STEM learning. Among the growing number of annual competitions are Globaloria’s “Globey Awards”, Advanced Micro Devices (AMD) “Changing the Game” contest, the Games for Change Awards, and Microsoft’s longstanding “Imagine Cup”. A more recent addition to this group is a competition issued by the White House itself, the National STEM Video Game Design Challenge. Developed in order to inspire K-16 students to learn STEM-based skills through direct application, this contest is now in its third year. It awards each of its winners in the middle school category with a personal laptop computer plus \$2000 for their respective schools. Over the initial year of the challenge, a total of ten middle school students were selected as winners from a total pool of 600 entries.

With no shortage of excitement, our classroom entered the competitive-fray. Using Scratch ([scratch.mit.edu](http://scratch.mit.edu)), we team-led an elective course around making one’s own STEM-based video game at an urban public middle school in which more than half of the student population qualifies for a free or reduced lunch. It was to be the school’s first elective around gaming, and we were offered the 2-3 PM time slot over the school’s Winter trimester (late October until mid-February) which met twice a week. Our elective attracted the most participants that term—a total of 17 students, 6<sup>th</sup> through 8<sup>th</sup> grade. The group was representative of the racial and ethnic diversity of the school with approximately 40% of the group describing themselves as “white”, 35% as “African-American”, and 25% as “Asian” or of “Mixed” race/ ethnicity. We designed the three-month elective around three goals: First, to support middle-schoolers’ math and science content knowledge with hands-on activity; second, to introduce children to the potential of computer programming as a vehicle for personal and creative expression; third, to expose children to more authentic audiences by becoming the actual producers of digital media and fostering a wider ethos of collaboration through sharing such media. Based on these three goals, we structured the elective course around both discussing and sampling games rather than simply teaching the class the basics of Scratch and then leaving them to their own devices. To this end, every class would open with a “roundtable” discussion in which students would discuss games and gaming, brainstorm potential ideas for their own ongoing designs, and sample and share examples of other STEM-based games from the Scratch

website. These round table discussions were paired with a series of “gallery walks” over the second half of the course in which students would play each others’ games and offer written feedback on game play and STEM integration; last, the course culminated with an in-class arcade in which the rest of the middle school was invited to come play the completed games before their final submission.



**Figure 1.** Screen shots of the completed games from the STEM Video Game Challenge. From the left: “Food Invaders”, “Lysosome Attack”, “Ender Build”, & “Genome Face”.

Out of the 17 students who participated in our Challenge elective course, 16 submitted fully working STEM video games by the mid-March deadline. Returning to our initial three goals for the course, it was clear that there had been considerable success. In terms of (1) STEM integration, over a third of the 16 participants (38%) developed their individual STEM video games “endogenously” focusing on a particular scientific phenomenon and/or mathematical relationship and developing a game around these learning principles for game-play. The other ten participants developed their games “exogenously”, starting with a particular type of gaming genre (e.g., a “platform game” or “first-person shooter”) and then subsequently “tacking on” the STEM theme into game play, extrinsically. In terms of (2) utilizing programming for creative personal expression, all projects effectively integrated a wide range of essential programming concepts: 69% of projects used coordination and synchronization as well as loops; 63% used event handling and conditional statements, and variables, and 19% used Boolean logic. In terms of (3) peer-collaboration and finding authentic audiences, this is perhaps where the course had the greatest measure of success. In the post-workshop survey on who or what served as their strongest influence, 57% of participants reported their fellow classmates, 36% reported us as instructors, and 7% listed the National STEM Video Game Challenge. Altogether, the class seemed to genuinely appreciate feedback from their peers, particularly when their classmates played drafts of their games.

Discussion will center upon potential future iterations of this model for reinforcing STEM learning and delve further into some of the unique challenges of using video games as a way to attract more children to STEM learning, including attracting a greater number of females to such elective coursework, pushing for more endogenic (rather than exogenic) integration of content, and ensuring that fostering a spirit of competition among students also leads to utilizing each other as resources for more authentic audiences and peer-to-peer collaboration.

## The Make-to-Learn Youth Challenge: Gaining Youths’ Perspective on Learning Through Making

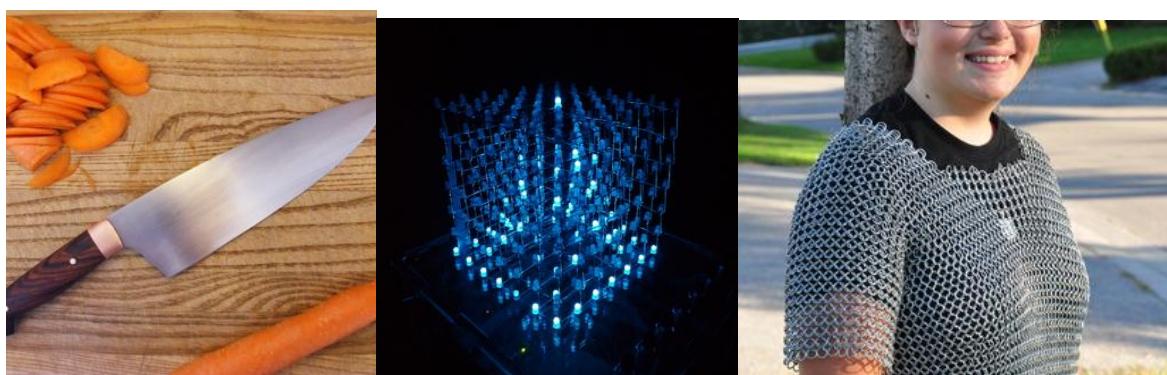
Kylie Peppler, Indiana University

The maker movement consists of a growing culture of hands-on making, creating, designing, and innovating. A hallmark of the maker movement is its do-it-yourself (or do-it-with-others) mindset that brings together individuals around a range of activities, including textile craft, robotics, cooking, woodcrafts, electronics, digital fabrication, mechanical repair or creation—in short, making nearly anything (Peppler & Bender, 2013). Despite its diversity, the movement is unified by a shared commitment to open exploration, intrinsic interest, and creative ideas. And it’s spreading: online maker communities, physical makerspaces, and Maker Faires are popping up all over the world and are continually increasing in size and participation (Dougherty, 2013). Moreover, there is a growing national recognition of the maker movement’s potential to transform how and what people learn in STEM (science, technology, engineering, and mathematics).

While we know from theory and prior research that making can be particularly beneficial in the learning process (e.g., Catterall, 2009; Peppler, 2013), most of what we know about in this area comes from studies within schools and after-school programs (e.g., Kafai, Peppler, & Chapman, 2009), and less from makers and maker culture at large. In the interest of developing a grounded understanding of youths’ own conceptions of learning from the process of making, we launched an online competition for young makers (between the ages of 13 and 18) to share and discuss their “makes” for the chance to win prizes ranging from gift cards to mini iPads. To increase visibility for the competition, we hosted the challenge on the preeminent DIY portal, Instructables.com, an online community for makers of all ages to document their original work, connect with

others, and gain inspiration. Challenge entrants were tasked to post one or more images and brief description of their make, which could be anything from a pinewood derby car, to a short movie, to science fair project. In an effort to uncover (a) the range of locations where youths' making was taking place (e.g., at home, in school, in afterschool clubs, etc.), (b) the range of practices involved in youth's making (e.g., working independently or collaboratively, etc.), and—perhaps most importantly—(c) what learning took place in the process of making, entrants had to answer the following questions in their submissions: (1) What did you make? (2) How did you make it? (3) Where did you make it? (4) What did you learn?

The Make-to-Learn Youth Challenge went live on Instructables.com in February 2013, with the entrance period closing 9 weeks later. At that point, a judging panel of 13 luminaries in the field of learning and making selected 20 projects (from over 300 submissions) to award with prizes. Submissions ranged from a “French” style kitchen knife made using a homemade grinder, propane forge, and milling machine; to homemade bracelets; to an Arduino-powered Analog VU meter that doubles as a clock (see Figure 2 below). Submissions fell into the following categories of project types: Arts and Crafts (48%), Electronics and Programming (14%), Shop projects (e.g., metal, wood, plastics, PVC, etc.) (12%), Fashion (7%), Mechanics/Engineering (7%), Digital Media (5%), Cooking (2%), and Other (5%). Over half of these projects were made at home (56%), with the remainder of projects being made within youth-serving organizations (28%), schools (9%), and hackerspaces (3%).



**Figures 2:** An array of projects submitted and reflected upon for the Make-to-Learn youth contest (<http://www.instructables.com/contest/maketolearn/>).

In terms of what youth felt they learned in the process of making, careful thematic analyses of youths' written reflections revealed that youth were less likely to state that they learned anything about subject-specific STEM content (17%) than they were likely to note general insights into the techniques for using tools and materials (e.g., how to use an exacto knife, raise fire temperature for forging metal, types of stitching) (33%), general habits of mind cultivated while making (e.g., perseverance, need for iteration, patience, setting reasonable goals, etc.) (28%), and observations of personal growth and social connections (e.g., “I learned that I liked...”, “I learned that I could...”) (19%). A small minority of youth (3%) reflected on learning about general entrepreneurship skills as they marketed and sold their makes. While implicit STEM content could still be taking place, it's clear that a sole focus on making as a STEM endeavor eclipses an important part of the learning that is happening in these spaces—and may neglect major genres of making which are important for preserving the broader maker ecology valued by young makers. In other words, by forcing an explicit STEM focus (particularly with electronics, programming, and, at times, shop projects placed central in this conversation), we may be overlooking the majority of young maker interests in the arts and crafts, fashion, and cooking, and digital media.

These findings suggest that the Maker movement can be inclusive of a diverse range of makers and leveraged to broaden STEM pathways. However, as we begin to think about leveraging maker culture in the learning landscape, how do we do so in a way that preserves the broader maker ecology and yet makes the potential connections to learning more explicit? How might the types of projects we promote in our educational workshops mutate the maker culture and constrain and enable the authentic learning goals? Lastly, there are some things that this data set cannot reveal to us, such as the extent to which this range of making is representative of non-dominant youth. Despite its promise, since most of this making occurs in homes and outside of any formalized context, how can we be sure that we are inviting youth from non-dominant communities to participate? Moreover, most of these projects require access to specialized tools, materials, and social networks to support such making that may have been prohibitive for youth to participate.

# Leveraging Online Design Challenges for Local Collaborations: Collab Challenge and Collab Camp

Deborah A. Fields, Utah State University; Ricarose Roque, MIT Media Lab

Studies of massive online communities tend to focus primarily on those online participants that are at the core of the community. But in truth, only a small percentage of youth demonstrate the fluency to participate online in ways that are the most educationally beneficial (Hargittai, 2010; Grimes & Fields, 2012). Given known barriers to participating online (e.g., Kafai, Fields, & Burke, 2010), we argue that online community events can provide unique opportunities for local groups to come together and work toward an authentic goal at the same time that they engage online participants with opportunities to deepen their participation. In this presentation, we discuss one such type of event, an online design challenge issued in the Scratch online community that we leveraged both locally and online to provide opportunities for deeper learning and broader participation in Scratch. As the largest online programming community for youth, deepening participation in the Scratch web community has strong potential for strengthening youth participation in programming.

In 2011 we sought to create a series of online events in Scratch that would bring kids together to program, learn, and collaborate beginning with Collab Challenge. With nearly 4 million projects shared since its public launch in 2007, the Scratch website is a vibrant online programming community for youth, with over 1,000 new projects being uploaded every day. Yet only a small percentage of online Scratch participants regularly engage in practices like commenting, downloading, and networking around projects (Fields, Giang, & Kafai, 2013). The Collab Challenge thus provided an opportunity to engage both online participants and students from locally organized workshops in productive practices they otherwise would not likely access in the larger, interest-driven online community. The online challenge had four key features intended to engage youth in deeper processes of computing and participating: external feedback, creativity within constraints, open spaces, and authentic audience (see Figure 3). Below we consider these design features in light of online and local participation in the challenge.



Figure 3. Scratch Collab Challenge: Call on main screen (left) and call details (right).

While most competitions (including those featured in this symposium) focus on a single endpoint of design, Collab Challenge and Collab Camp required two submissions: a draft and a final project. All submissions received *external feedback* from the Scratch Design Team in addition to goodwill comments left by other participants to help users improve their designs. Half of the 52 teams with 139 participants submitting projects online took the opportunity to resubmit their projects, most of them going deeper in programming in the second version. In addition, many participants left comments on others' projects, though not as many as we had hoped. Participants also submitted a range of projects, demonstrating that even within a shared task (design a project using three pre-chosen images: a pinwheel, a swirl, and a beachball), users were able to use *creativity within design constraints*. Participants submitted a wide range of stories, games, and interactive animations. Further, based on the number of comments and views tallied on Collab Challenge projects at both the draft and the final stages, the Challenge provided an *open space* with a wide horizon of observation (Hutchins, 1995) for participants to see others' projects, download them, and get ideas from them. Finally, the Challenge provided highly desired visibility on the Scratch website. This was instantiated in two ways. First, 14 of the best projects were "featured" on the front page for a week at the end of the Challenge. Participants strongly sought out this verification of their quality participation as it gained them a wide audience for their work. Second, simply by posting projects in the Challenge gallery, projects culled far more views than normal for projects submitted on the Scratch website. Thus the Challenge provided a means for online participants to have a wider audience for their Scratch work.

Locally we organized a workshop for students from a local high school to engage in the Challenge. Twenty-one high school freshman aged 14-15 participated in the 8 week (2 hours/week) workshop, forming six small groups. All students had prior experience with Scratch but none participated in the website regularly. In this way the Collab Challenge drew in students who otherwise did not feel very engaged in the Scratch website. According to even the most involved Scratch students (who played Scratch in their free time and helped to mentor others), they rarely logged on to the Scratch website unless requested by a teacher. Yet the *external feedback* left on their projects online had a strong influence on students' projects, particularly because it came from people seen as outside experts. As Jacob described about his group, "They took all of the criticism to heart and all the praise, and they worked hard to make their project more interesting." Individual students and groups as a whole read the feedback and make specific changes in their projects in response. We suggest that the external feedback from members of the online community held more status for local students because of the perceived expertise and authenticity the members. All local groups improved their projects substantially between the first and second submissions. In local workshops *open spaces* took two forms. Online, students could view many other groups' projects, download them, and open them to see how they worked. This gave them a wider perspective on how their work fit in with others' creative ideas and sophisticated programming. In addition we created hourly sharing times in the local workshops where students showed their in-progress project to the larger workshop and received praise and constructive feedback. This not only encouraged the individuals who shared their projects, it also created an open space where students could learn from each others' work, get ideas, and see different programming strategies.

The Collab Challenge provided a structure for students to work creatively and an audience that changed students' visions for who saw their work and how their work was perceived. Although *audience* is most often discussed in literacy studies (Magnifico, 2010), we found that it played a key role in students' programming. While all students in local workshops had their peers as a local audience, knowing that their project would be viewed online by other participants in the Collab Challenge "was helpful because it gave them perspective on their works," according to one student Sam. "It kind of made them realize that other people were going to see this too and it motivated them to put more work into it." Thus locally, the online audience gave students a wider perspective on their programming and they made more efforts to put in instructions and improve their projects. Online participants responded positively to the feedback that others left and Our experiences of leveraging and building on key features of online design challenges suggest further ways to build on opportunities normally taken up by only a small percentage of online participants.

In future iterations of the Collab Challenge we anticipate making several design changes to better facilitate Scratch users' deepening participation in key programming and online media practices. For instance, we hope to better understand the ways in which a broad audience and constructive feedback affect students' actual learning of specific programming concepts. In particular, user interaction and initialization are two key areas that we suspect could be improved through such design challenges since they depend on projects running consistently without a person present to guide and direct users through a project. In addition we plan to promote constructive criticism amongst all participants in the Challenge, not just the Design Team. This should encourage users to create a more open space to view others' projects as well as critique and encourage others. Overall, the Collab Challenge showed good potential for engaging both online and local youth in going deeper into programming while also encouraging stronger engagement with a key interest-based community that could support their programming practices.

## eCrafting Circles: Rethinking Celebrations in Online and Offline Communal Makerspaces

Yasmin Kafai, Orkan Telhan, University of Pennsylvania, and Karen Elinich, The Franklin Institute

Much attention has focused on designing makerspaces either as physical spaces such as fablabs and museum spaces that provide access to 3D printing and other devices for manufacturing computational artifacts, or as online spaces such as Instructables, diy.org, or make2learn that allow for sharing of designs and instructions, or as public events such as Maker Fairs or online competitions that bring together groups and celebrate local productions (Honey & Kanter, 2013). Far less attention has focused on creating hybrid models that allow for local fabrications but also provide global connections. In our presentation, we describe the design and implementation of such a hybrid model called eCrafting Circles (see Figure 1) that bring together these different efforts by providing local communities and workshops with an online home, or circle, in which they can share designs of their artifacts and by providing access to a larger community that can offer support and feedback. Rather than focusing on competitions as a model for incentivizing making, displaying, and sharing handmade artifacts, eCrafting Circles leverage traditions of sewing circles which are themselves built upon the collaborative model of quilting bees that produce shared artifacts and celebrate diversity in accomplishments.

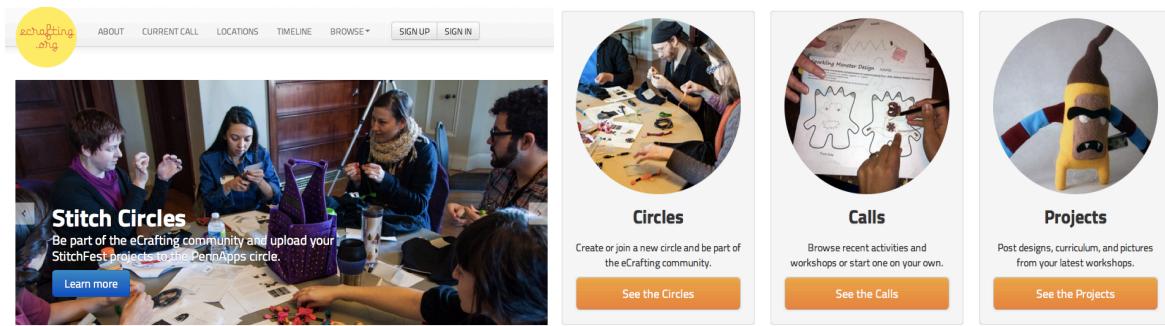


Figure 4. eCrafting.org: Main screen upper part (left) and lower part with different activities (right).

The design of the eCrafting Circles platform provides basic features for individuals and groups to sign-up and create their local activity groups. A location map, an activity timeline, and project archive let activities, calls, and projects be browsed freely by everyone. Online visitors can comment on the projects, ask to be invited to join circles where they can either work remotely with circle members on existing projects—during or after workshops—or join upcoming events and workshops to be part of new activities. Unlike most online communities that are geared towards the creation, display, and archival of individual projects, eCrafting Circles intend to motivate a social learning experience through organizing activities tied to public events. As the website allows individuals, groups, maker spaces, and institutions initiate their own circle and form their own calls, such groups can structure their own curriculum and pursue different types of learning objectives such as making socially integrative projects—such as designs that foster parent and child interactions—or commemorative artifacts, and memorabilia. Circles are supported by providing teaching aids, templates, instructions, and materials for a set of predefined themes—such as Monsters and Masks for Halloween, T-shirts for Astronomy night—and allow the circles customize the material for their own events.

In our first local implementation we issued two calls, *Monsters & Masks* in Fall 2012 coinciding with celebration of Halloween night and *Astronomy Night in Philadelphia* in Spring 2013 connecting to an annual city-wide event during the Philadelphia Science Festival to bring eCrafters and their families together. Several workshops at The Franklin Institute, in different branches at the Free Library and other community organizations and schools had students and adults stitch circuits with LEDs and switches on masks, monsters (abstractly-shaped stuffed creatures), t-shirts and interactive hoodies. In addition, we organized a meeting in a centrally located public park that also provided portable telescopes as part of Astronomy Night. Dozen of parents participated in making simple circuits with their children while a small group of eCrafters had brought their interactive hoodies and linked their hands while touching conductive patches to form a human circuit that lit up their LED designs. Our analyses of pre-post surveys found success in that the over 100 participants ranging from 10 to 50 years of age broadened their views of computing and increased their interest in searching out more activities in computing while also significantly improving their understanding of simple circuits and electricity concepts. We also learned that attendance at local events is not guaranteed, even when connected to initiatives such as Astronomy Night that receive widespread advance publicity.

These experiences and evaluations prompted us to rethink the role of public events in reaching out and connecting to local and online community members. Rather than using public events to celebrate final accomplishments, we will use them as a launch pad to generate interest and showcase designs. An intense 48-hour local event, called PennApps, will serve as anchor to engage 100 undergraduates in generating new applications with the LilyPad Arduino while across the city children and their parents at The Franklin Institute as well as youth in participating branches of the Free Library will engage in simpler designs but joining the larger community online all the same. Our aim is to support the activities both during and after the workshops, so that the learning and sharing experience can be sustained after the initial contact among the circle members. Here, circles can continue to grow with non-local participants and continuously be in dialogue with other circles. The website provides also a visual interface through which circle members can upload pictures and videos of their individual projects and share code, craft and design techniques with each other. They can also embed annotations, comments and explanations to their own designs and mix their content with different elements they appropriate from other designs. By participating in eCrafting Circles, all participants can bring local funds of knowledge and experiences to bear in the design of their artifacts and find access to local and collaborative communities of practice, further suggesting that the eCrafting Circles model may have broad potential impact for the informal science learning community.

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# Research and Design of Learning Experiences for Families

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**Abstract:** In family activity children learn how to be participants in family practices, how to be learners and teachers within family relationships, and to approach learning and knowing in ways valued by their families and communities. Increased attention to children's learning across contexts highlights that meaningful learning can be ubiquitous across time, space, and situations. However, we need more understanding of how learning can be constructively linked across facets of children's lives, especially as they move through the world with their families. This poster symposium brings together people working on research and design of family learning experiences, in a variety of contexts. We aim to further understand 1) processes of learning across practices, time, persons and social/physical contexts, 2) the nature of learning processes in families, considering varied goals, values, and possible learning situations, and 3) what is being learned from new forays into research and design for family learning environments.

## Symposium Overview

Families play a prominent role in children's learning about the world around them, and families are an obvious context in which children learn to become a certain kind of person ("becoming in practice"). For example, children of politically engaged parents often become politically engaged as emerging adults (e.g., Dinas, 2013), and family attitudes toward and engagement with science contributes to whether children see science as an identity or trajectory that they can pursue (e.g., Archer et al., 2012). In family activity and conversation children learn how to be a participant in family practices, learn how to be learners and teachers within family relationships (e.g., Goodwin, 2007; Ochs & Taylor, 1995), and learn to approach learning and knowing in ways that are valued by their families and communities (e.g., Rogoff, 2003). In many ways, family life sets the stage for children's learning both at home in the early years as well as throughout their diverse activities across their lives.

Although schools have long made efforts to involve families in their children's learning, and museums and other informal education institutions often design for learning with attention to how adults might play a role in children's learning experiences (e.g., Crowley, Callanan, Tenenbaum, & Allen, 2001), designing for family learning in its own right is less represented and research on family learning in informal settings is slowly converging on a coherent disciplinary framework (Ellenbogen, Luke, & Dierking, 2004). This is the case even at a time when increased attention in research and theory about children's learning across contexts highlights that meaningful learning can be ubiquitous across time, space, and situations (e.g., Connected Learning Research Network; Ito et al, 2013; LIFE Center). A growing body of research on Science, Technology, Engineering, Art, and Math (STEAM) learning in the home and other everyday or informal settings suggests that engagement with STEAM ideas is fluid across settings and activities, and can look very different from what happens in school. For example, Barron, Martin, Takeuchi, & Fithian (2009) have found that family members

support children's interactions with technology in a variety of ways including collaborating and providing information and resources. In math, families draw on cultural resources, values and mathematically-relevant problem solving to accomplish everyday goals that include budgeting and planning for a special event, making home improvements, and engaging in leisure activities (Goldman et al., 2010; Pea & Martin, 2010).

These sorts of studies point the way towards the need for more understanding about how children's learning can be constructively linked across varied facets of life. For example, how does a child transfer her understanding of a biology concept from her classroom science lesson to a nature walk with her parents? How do the media practices of a family shape the epistemic practices of media use elsewhere? How do families translate and/or adopt learning practices imported by group members through new tools, toys, or shared activities? How can learning design respond to and be effective in these contexts? In contribution to answering questions like these, this symposium brings together people working on the research and design of learning experiences for families in a variety of contexts. As a community of analysts, researchers, and designers, the collective aims to further understand 1) processes of learning across practices, time, and social/physical contexts, 2) the nature of learning processes in families, considering the varied goals, values, and possible learning situations, and 3) what is being learned from new forays into research and design for family learning environments.

The work represented in this symposium is grounded in the premises that children and their parents interact successfully with many kinds of learning opportunities in their everyday lives and that well-designed resources and tools can help families engage in collaborative learning. Symposium participants will address challenges and lessons learned from designing for and researching family learning, and we aim for attendees to participate in a discussion about translating research findings into design principles. This symposium will address the research and design of learning experiences for families by focusing on the following issues:

1. Developing case studies of family learning processes in informal environments
2. Identifying the unique challenges in researching and designing for family learning
3. Leveraging design to provide opportunities for *collaborative* learning processes in family activity.
4. Understanding how research and the design process work together in family learning/family-focused environments.

We bring together eight posters that present studies of family learning in the following contexts: gardening in the backyard, exploring museum and botanical garden exhibits, nature walks and beaches, playing video games and engaging in other media use at home. The learning activities that are studied span topics in science and media: astronomy, identifying and observing plants, soil testing, exploring natural features of a beach, and learning through computer and iPad® games. This body of research and design of family learning processes draws upon socio-cultural, informal learning, and joint media engagement theory and research (e.g., Nasir, Rosebery, Warren, & Lee, 2006; National Research Council, 2009; Takeuchi & Stevens, 2011), and employs a variety of analytic lenses including case studies, interaction and conversation analysis of video-recorded activity, and mixed-methods approaches including video, questionnaires, and interviews (e.g., Jordan & Henderson, 1995).

In addition to brief descriptions of each poster here, separate poster abstracts are listed in the next major section. Jennifer Jipson and Maureen Callanan present research on young children's concepts of astronomy and family conversations about astronomy. They have collaborated with educators and museum exhibit designers to create astronomy activities for families with young children, and they will offer reflections on how to effectively navigate combined research and design collaborations. Jessica Umphress introduced a designed activity (soil testing kit) into families' established gardening practices. She presents in-depth interaction analysis of questioning and epistemic practices used when exploring the science kit. She also analyzes the features of the designed activity that may have contributed to the results.

Megan Luce, Shelley Goldman, and Tanner Vea designed playful, exploratory learning experiences for families that provide science-related activity prompts and conversation starters at various locations and environments. They present analyses of the ways that family members engage in science-related activities at a local beach. They also discuss the potential for location-based science learning activities to offer learning opportunities that are flexible and fit with families' varied goals and interests. Heather Toomey Zimmerman and Lucy McLain also designed for collaborative discoveries and conversations on self-guided nature walks. They present research on how their designed learning tools functioned in family processes of identifying plants and other features in nature. Their research highlights the need for family learning materials that can be flexibly used by families within forms of social interaction.

Catherine Eberbach studied how families observed and discussed pollination at a botanical garden. She offered parents simple "instructions" in conversational strategies (e.g., asking *wh*-questions) they could use to engage their children. These strategies evoked elaborative talk and encouraged shared noticing of phenomena. Catherine will discuss how conversational strategies may be a transportable tool that can be used across contexts

to facilitate *collaborative* family learning. Carrie Tzou and Elyse Litvack designed science backpacks, with activities related to current science content in school, which children could check out from school and take home. Based on videos the families took of themselves, Tzou and Litvack report on the ways in which families appropriated the backpacks at home, and offer insights into designing for family learning that straddles home and school.

Sinem Siyahhan reports on a design-based research study that investigated the effectiveness of different game design elements in supporting collaborative intergenerational play experiences where parents and children reciprocally take on expert and novice roles. She will offer insights into how video game-based learning experiences can be designed to position parents and children as learning partners. Amber Levinson reports on in-depth case studies of how Latino immigrant families use media at home. She also introduced an iPad® into the families' homes to better understand the roles that media devices come to play in family life and learning. This research has implications for potential innovation in designing for family learning through media.

### **Poster Symposium Format**

The symposium format will include a 10-minute introduction by the co-chairs, followed by 50 minutes of browsing posters, and the final 30 minutes will be used by the discussant to synthesize and comment on the presented work and to facilitate questions from attendees.

### **Discussant**

Dr. Philip Bell, University of Washington and the LIFE Center, will provide synthesizing remarks based on his expertise in informal learning research and theory. The issues addressed will align with the main issues of the symposium: 1) How do we move forward as a field in research on family learning processes in informal environments? 2) How can we expand our methods in family learning research? 3) How can design be leveraged to provide opportunities for collaborative learning processes in family activity? Dr. Bell will also co-facilitate, with the chairpersons, a question and discussion session with attendees and presenters.

### **Individual Posters**

#### **My Sky Tonight: Researching Young Children's Ideas about Astronomy and Designing Informal Astronomy Activities for Families**

Jennifer Jipson, Cal Poly, San Luis Obispo, jjipson@gmail.com  
Maureen Callanan, University of California, Santa Cruz

In this collaborative project, cognitive developmental and educational researchers are working with astronomy educators to study preschool-aged children's conceptions of astronomy, and to develop and test new activities for preschool children and their families. The focus of the design project is to develop developmentally-appropriate astronomy activities for 3-5 year-old-children and their families to engage with at planetariums, nature centers, and other informal learning environments. To explore the ways in which families engage in everyday conversations about nature, including astronomy, we conducted a two-week diary study asking parents to keep track of their children's conversations about nature. Sixty families participated; while the majority of parents are highly educated and largely European-American, we also included a targeted sub-sample of 15 Mexican-heritage families with basic schooling. We also invite the same families to visit a local museum where prototype astronomy activities were being tested, and observed family interactions. In this poster symposium we will report on preliminary findings regarding (1) the frequency of preschool children's spontaneous conversations about astronomy, presence of talk about causal mechanisms and evidence, and how these conversations vary by age, gender, and schooling background of parents, (2) observations of preschoolers and parents' collaborative engagement with workshop astronomy activities, and (3) reflections on the challenges involved in such a combined research and design collaboration.

#### **Complex Family Questioning Around a Garden Soil Science Kit**

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Northwestern University

Families often have shared internal practices, interests or hobbies that can be the site of rich learning and conversations. Some of those practices, like gardening, can naturally span generations and involve informal apprentice-type relationships where knowledge is passed down to younger gardeners during the act of gardening together. Do these relationships and activities leave room for both children and adults to ask questions and meet each other on equal epistemic footing, or are they epistemologically hierarchical?

In this research 10 gardening families with children ages 7-12 years old videotaped themselves doing a science kit about their garden soil in their own homes. The kits involved a multi-part activity wherein the

families collected a soil sample, manipulated it to make it testable, combined the sample with different chemical reagents to reveal nutrient levels and other properties, interpreted the results, and applied them to their own gardening plans and experiences. The learning goals for the kit included having the families be able to talk about the relationship between soil and plants, and being able to make meaningful connections between those ideas and their own gardens. One research goal for the activity was to reveal the epistemological properties of parent/child interaction around their shared practice of gardening together. Who would be the knower and how would knowing get done or knowledge be built while using the science kit?

Analyses of question practices in the resulting videos reveal an interesting and complicated epistemological relationship between parents and children around the science kits. For example, analyses show that while parents did take a fairly managerial stance towards the activity, they also engaged in deliberate and genuine information-seeking and worked to solicit their children's opinions about what was being revealed by the kit. In turn, children actively engaged in asking questions about the activities and results, and also asked frequent repair questions (e.g. Schegloff, 1992) to ensure that they were understanding what was happening and the relationships between the chemical properties of their soil and their garden plants. Further analyses show that although functionally parents' questions are doing real epistemic work with their children, more than half of them were simple polar questions (i.e. requiring yes/no responses). On the other hand, more than half of children's questions used question words (e.g. what, where, why, etc.) that place a greater demand on their recipient by requiring more complex responses. Is this a meaningful disparity in how the work of knowing gets done in this setting, a developmental difference in how questions are asked, or simply an artifact of the design of the science kit? These and other results will be shown in the poster.

## **Evolving Participation Structures in Family Science Activity**

Megan Luce, [mluce@stanford.edu](mailto:mluce@stanford.edu)  
Shelley Goldman, Tanner Vea  
Stanford University

In our efforts to design and research playful science learning experiences for families with young children (4- to 11-year-olds) we created activities and conversation starters that are meant to engage families in science exploration "any time, anywhere." Drawing upon socio-cultural and informal learning theory and research, we aim to design science-relevant activities that are exploratory, fun, open-ended, and that spark conversation and collaborative sense-making about the world (e.g., Allen & Gutwill, 2009; Hammer & van Zee, 2006). Our goal is to prompt children and families to explore the world, be inquisitive, and use their senses to observe, discuss, reflect, and learn. The experiences we designed locate points of interest in the environment and cue families as to how they might engage, question, and explore (see also Zimmerman & Land, 2014) without the need for specialized tools, instruments, or objects. The content and science exploration prompts are generally in the purview of, and benefit from, parents and children's cultural understandings and funds of knowledge (González, Moll, & Amanti, 2005). For example, one set of activity prompt invites families to predict and test what will happen when they throw a buoyant ball into the ocean waves...

What do you think will happen if you throw a ball out into the waves?  
Throw the ball out into the water and see what happens!  
Does the ball tell you anything about wave patterns, rates, or direction?  
Try this: each person chooses a spot on the beach where they think the ball will come back to.  
Throw it out! Who guessed closest?

In this poster we present case studies of families pilot-testing a set of activities designed for exploration at coastal environments. Three families used wearable GoPro® video cameras to record themselves during a trip to a beach. The activities were available for view on a mobile device, but each family chose to use the print-outs we also provided them.

As one lens on understanding family learning processes over time, we focused the video analysis on the various ways that family members engage each other and with the activities over time during their trip (Jordan & Henderson, 1995). From studies of informal science learning we know that parents and children may take a variety of roles during museum visits, and parents ask questions, provide explanations, and help children frame their experiences (Callanan & Jipson, 2001; Zimmerman, Reeve, & Bell, 2008, 2010). We present analysis of "participation structures" (Philips, 1972) that emerge and change as families navigate science activities and conversations outdoors. We report case analysis for three families, which indicate that 1) families move through a variety of stances including questioning, being an expert, being skeptical, and rescuing interests, and 2) collaborative sense-making seemed to be facilitated when both parents and children didn't know the "answers" or when they came across surprising phenomena or inconsistencies in their ideas and observations, 3) epistemological orientations (what counts as "knowing," how we know, who knows) shift over time and in

relation to phenomena under consideration. We discuss the potential for our location-based informal, or casual, science activities and conversation starters to contribute to playful family science learning that can take many forms within and across families. We offer suggestions for design principles of science-relevant activities and conversation starters that families can do “anywhere.”

## **Designing for Collaborative Discoveries and Conversations: Families Together Outside**

Heather Toomey Zimmerman, haz2@psu.edu  
Lucy R. McClain  
Penn State University

Our research project examined families' interactions with each other and the outdoors in order to develop materials for families that would spark playful scientific explorations on nature trails. Our goal is to understand how to support people as they engage in questioning and explanation-building (see Allen & Gutwill, 2009) in the life sciences. A conceptual framework based on informal learning research and sociocultural theory situates our project. Thinking and learning in everyday life is often guided by family interactions in a process called guided participation (Rogoff, 2003). Guided participation occurs in informal settings when family members mutually support each others' sense making (Callanan & Jipson, 2002; Crowley & Jacobs, 2002; Palmquist & Crowley, 2007; Zimmerman, McClain & Crowl, 2013). We build on research (e.g., Eberbach & Crowley, 2005; Rowe & Kisiel, 2012; Zimmerman & McClain, 2012) that asserts that guided participation allows children and parents to connect new biological knowledge outdoors to shared family experiences and other forms of prior knowledge.

Participants in our study were families attending nature walk programs on a wheelchair and stroller accessible Americans with Disabilities Act compliant trail outdoors. Families were ethnographically shadowed as they interacted together, with a subgroup of families videotaped for deeper analyses (Derry et al, 2010). Collective case studies (Stake, 1995) were created through video-based analyses of learning processes found in families' interactions.

Across the families in our study, more prolonged exploration of natural objects occurred when a child initiated a 'discovery,' rather than a naturalist or a parent. Our findings showed that when families used scientific tools to support observations, these investigations were tied to families' goals to identify the discovered animals, plants, fungi, and abiotic elements. Correct identifications of species most often required a complex coordination of tools, scientific representations, and families' conversations and social interactions. Two common interaction patterns emerged from the video analyses: (a) discovery first, followed by tool and representation use second and (b) selection of a tool and representation first followed by trying to find an object to identify. Implications were drawn on designs that support family learning processes, including the need for materials that can be flexibly used by families within forms of social interaction.

## **Facilitating Collaborative Observational Practice During Family Activity**

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A central challenge of scientific observational practice is to reach agreements about what an individual sees with what others see (Daston, 2008). To address this challenge, scientists have forged cultural tools—language, equipment, and disciplinary systems of knowledge and practice—that enable the collaborative construction of shared vision (Goodwin, 1994). Yet little is understood about how people begin to participate in these scientific observational practices (Eberbach & Crowley, 2009). This study explores how parent knowledge and use of conversational strategies mediated joint attention, knowledge sharing, and collaborative agreements during an observational activity.

79 parent-child pairs that included children aged 6-10 observed and talked about pollination during a visit to a botanical garden. Families were organized by parent knowledge of pollination and randomly assigned to treatment or control groups for parent conversational strategies. To help parents elaborate upon children's observations, parents in the treatment groups received instruction in the use of particular conversational strategies (e.g., asking *wh*-questions, focusing talk on children's expressed interests). Family interactions were videotaped, coded, and analyzed. Statistical analyses revealed that a simple training protocol significantly modified how parents interacted with their children. Case study analyses suggested that parents' use of the *wh*-questions strategy facilitated participation, clarification, and focusing attention. In turn, these questions evoked elaborative parent-child talk and extended shared noticing of phenomena. Parents' use of the focus talk strategy shifted how parents actively managed children's attention in ways that also enabled collaborative observations and knowledge sharing, but from the perspective of the child.

This study expands our knowledge of how families collaboratively practice science together in

community settings. “Designing” for parent conversational strategies can support interactions between parents and children in ways that foster collaborative observational practices and knowledge sharing. One way to frame these findings is to think about the use of parent conversational strategies as transportable tools that can be applied across learning contexts to support joint attention and talk in ways that help parents and children to collaboratively see the same things during observations.

## **Backpacks as Boundary Objects: Documenting How Families Appropriate Take-Home Science Backpacks**

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Elyse Litvack

University of Washington Bothell

The goal of this research project was to design, implement, and study a science backpack program that connects elementary school science learning with science activities that can be done at home with families. Specifically, we designed mini science kits that contain simple materials, directions, and ideas for conducting scientific investigations at home that connect conceptually to science being learned at school. The backpacks served as *boundary objects* (Akkerman & Bakker, 2011)—as such, they potentially allow for science practice at home that is infused with rich and varied funds of knowledge present in the home. Research questions we asked were: (1) How did the backpacks as boundary objects get appropriated by the youth and their families at home?, (2) What roles do parents take on while engaged with the backpack activities and how do these roles position children as science learners?, and (3)What are implications from this study for designing boundary objects that cross from school to home (and vice versa)? As a theoretical framing, we used a modified version of cultural historical activity theory (CHAT) (e.g., Cole, 1996) which allowed us to understand how boundary objects can transform roles, division of labor, and mediating tools from one activity system (e.g., school) to another (e.g., home).

We placed digital cameras in the backpacks, and the videos made by families and youth were analyzed for the ways in family members took on various roles while engaging with science learning that subsequently positioned youth in certain ways and how youth and their families transformed (or did not transform) the science activities into new types of activities. We found three main types of appropriation of backpacks by youth and their families: (1) appropriating school roles in which traditional power relationships between “teacher” (usually an older sibling or parent) and “student” (the youth who checked out the backpack) were recreated, (2) hybrid appropriation, in which parents and youth share positions of power and expertise, and (3) repurposing appropriation, where the backpack activities were turned into occasions for youth to host “reality tv”-like episodes as they recorded themselves engaging in the activities. This study points to the need to design for multiple configurations of learning, with activities that suggest various roles that parents and youth can take on.

## **Intergenerational Play Around Video Games: A Context for Family Connection and Learning**

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Intergenerational play around video games provides unique opportunities for families to connect and learn together (Aarsand, 2007, Horst, 2009). At the same time, the nature of intergenerational play around video games varies across different families, with some parent-child interaction styles and patterns being more productive in supporting family connection and learning than others (Mitchell, 1985; Siyahhan, Barab, & Downton, 2009). Using the lens of a socio-cultural theoretical framework, this presentation reports on findings from the second iteration of a design-based research study that investigated the effectiveness of different game design elements in supporting collaborative intergenerational play experiences where parents and children reciprocally take on expert and novice roles and engage *mutual scaffolding* behaviors. To this end, 16 mother-child pairs (children ages 9 to 13) played through different science, language arts, and social games designed in Family Quest—a family game space created within Quest Atlantis, a three-dimensional educational gaming environment ([www.QuestAtlantis.Org](http://www.QuestAtlantis.Org))—as part of a family program at different informal learning sites. Data sources include parent questionnaires, video recordings of parent-child gameplay, and semi-structured interviews with parents and children about their experiences playing together. This presentation will share findings on parent-child interactions around different game designs, and provide illuminative cases of collaborative intergenerational play experiences that support family connection and learning. Results from this study contribute to our understanding of the nature of computer-mediated communication and learning between parents and children, and how to design learning experiences for families in the context of video games that position parents and children as learning partners.

## Tapping In: Latino Immigrant Families, Media and Learning at Home

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This poster shares design-relevant findings from a dissertation study that investigates how low-income Latino immigrant families with young children use broadcast and digital media. Media – on television, computers, mobile devices and other platforms – has become a substantial part of families' language and literacy environment but its role is little understood. Using a lens of joint media engagement (JME), the study looks at how both children and parents use media at home and the opportunities to design educational content for this population. In these families, multiple generations are learning a new language and media often constitutes the only presence of that language (English) within the home. The study takes a three-pronged approach that includes:

- 1) ethnographic case studies to provide rich and detailed data on this little-studied topic;
- 2) survey responses that are compared to a nationwide sample, and
- 3) an intervention wherein I distributed a tablet device (iPads) to each case family and documented the role it comes to play in family life and learning.

The case studies provide rich data regarding media practices and interests within families, while the intervention gives a glimpse of what opportunities and/or challenges a new technology can bring and how families take up these media tools. The poster will share both qualitative and quantitative results related to how participating families – who all have at least one child between the ages of five and seven and speak Spanish as their primary home language – use media for learning. The poster will also focus on how to identify within these findings potential design spaces for innovation.

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# **Re-Placing the Body in Children's Learning**

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## **Symposium Overview**

In this symposium we present four recent design studies with young people that leverage *bodies-in-place* as an opportunity for *making sense* of and *taking place* in practices. Our common aim in this session is to contribute to a more robust theory of embodied cognition by providing descriptive and comparative analyses of how young people make “body sense” (Cajete, 2000) of the places in which they are engaging. In a recent special issue of *Journal of the Learning Sciences*, researchers provided further evidence and arguments for the centrality of the corporeal for learning mathematics (Hall & Nemirovsky, 2012). While that work has most recently promoted embodied cognition as a viable theory of learning, educators and educational researchers still struggle against the tendency to fetishize abstracted, “pure knowledge” over the ways in which our moving, feeling bodies make sense of the world. Additionally, and as Stevens (2012) pointed out in his commentary to the “Modalities of Body Engagement in Mathematical Activity and Learning” *JLS* Special Issue, attempting to build a broad understanding of how the body and learning relate via solely classroom-based studies is a major limitation to robust theory-building. Thus, our collective narrative provides a (literally) grounded account of embodied cognition that problematizes the absence of space and place in previous accounts of learning.

Knowing how to make learning relevant and salient for young people across content areas is a recurring question in our field. As designers for this work in mathematics, ecology, media production, and geography, we were informed by ideas put forward by studies of inquiry-based curricula (e.g., Salierno, Edelson, & Sherin, 2005), “reality based education” (Emdin, 2010), families’ funds of knowledge (e.g. Moll, Amanti, Neff, & Gonzalez, 1992), and hybridity and thirdspace practices (e.g., Taylor & Hall, 2013). Building upon these concepts to increase learners’ agency and engagement, the four design studies presented here explicitly resourced the mobile bodies of young people with tools for “hacking” the traditional uses of places for new and emergent purposes. For example, in one study (Taylor), teenagers wore GPS devices on their wrists to walk and inscribe a personal message over the terrain of the neighborhood. In this sense, a place that was once a geography of mundane activity became a canvas for authorship through which new realizations about the built and developing environment emerged. In another example (Ma), groups of middle school math students were given ropes and lawn flags to transform the football field into a large-scale, 3-dimensional space for geometric problem-solving. And in yet another example (Phillips), spatially-indexed demographic data sets were made visible to high school media production students to create a counter-narrative of the imagined geography and spatial arguments contained in a map. In this way, unlikely places, in combination with bodies and tools, became unconventional portals to youth agency and learning/production.

Our design studies with young people intentionally leveraged bodies as a resource for learning in *dynamic* relation to a particular geography that was *outside* the classroom. These places varied in scale and provided different affordances and constraints for the interacting bodies of learners. A football field, an urban forest preserve, a neighborhood, and the imagined geographies of faraway places are the examples of place conjured in this symposium, the particularities of which invoke Geertz’s (1983) comment that “no one lives in the world in general” (p. 262). Each setting provided unique challenges for the bodies of learners that are typically distilled out of classroom activities; intense humidity on the football field, damp socks in the forest preserve, swarming cicadas in the neighborhood streets, and natural versus “relaxed” hair in the production studio, were not *obstacles* to learning, but were intrinsic and necessary parts of how young people made sense of geometric problem-solving, ecological observational inquiry, spatial analysis, and map argumentation, respectively. However, it is not the particularities, but the over-arching similarity of these seemingly disparate places that makes them so interesting for a story of embodied cognition; no matter the scale or the configuration of the activity within each place, the gendered, cultured, and racialized bodies of learners exploded the identifiable boundaries (Nespor, 2008) of painted lines, signposts, highways, or state borders to make an embodied history present in every moment of learning and engagement.

The four design studies in this proposed symposium used common data collection and analytic methods to understand and explicate the relevance of bodies-in-place for young people's learning. We captured detailed video recordings—often with the help of our participants—of collaborative engagement, problem-solving, and production during “on-the-move interventions.” Both Marin and Taylor, for instance, asked study participants to wear cameras as they navigated the forest and neighborhood. Mobile video recordings helped us to see the different resources in circulation and how new resources emerged depending on the changing location of participants. Moreover, through video records, we saw that new geographies elicited new actions. Gestures, facing formations, and stopping and starting sequences were co-constituted by the activity, the coordinated objectives of the participants, and the challenges and affordances of the place. Our analyses followed from theory and observations that meaning making occurred through all of the senses and possible arrangements of the body in relation to setting and activity. Multimodal (Kress & van Leeuwen, 2001; Norris, 2004) and microanalyses of interaction (Jordan & Henderson, 1995) allowed us to see that performance genres—“a set of specific forms of embodied action” (Stevens & Hall, 1998; p. 108)—were much less predictable when the terrain of interaction was constantly in flux (e.g., weather, hills, marshes, missing signage, eroding roads).

The influential exchange between place and body has been a topic of renewed interest during the corporeal turn in social science (e.g., Evans, Davies, & Rich, 2009). And while the learning sciences have welcomed a resurgence of research that presents the body as central to cognition, there is still very little work that contributes to a theory of embodied cognition by investigating novel practices in “naturally-occurring” places. The following talks do just that by offering new methods, new units of analyses, and new concepts from research working within the theoretical framework of embodied cognition.

## **Re-Placing the Body in Walking Scale Geometry**

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This paper describes findings from part of a design study investigating how middle and high school students engaged in a learning setting called Walking Scale Geometry (WSG). These tasks took students outside to a grassy field to construct, transform, and answer questions with and about large-scale geometric objects. The objects were constructed by students with everyday objects such as ropes, lawn flags, and their own bodies. The purpose of this paper is to share two findings from the study with respect to student bodies in dynamic relation to place. These findings problematize typical views of what counts as appropriate and productive in schooling and in mathematics learning. I will begin with a brief overview of the design and framing and the data and methods used in the study, then proceed to a summary of findings.

### **Design and Framing**

WSG was designed to promote hybridity (Gutierrez, Baquedano, & Tejeda, 1999) in geometry learning—the design was meant to help students make connections to out-of-school funds of knowledge (Gonzalez, Andrade, Civil, & Moll, 2001) or repertoires of practice (Gutiérrez, & Rogoff, 2003) in order to support the emergence of a transformed learning setting that inextricably incorporates students' sense-making with classroom disciplinary practices and learning goals. Unlike previous studies of hybrid learning settings, where instruction was designed to bridge school content with home resources (Calabrese Barton & Tan, 2009), or unexpected incidents were capitalized upon (Gutiérrez, Baquedano, & Tejeda, 1999), WSG tasks were meant to *disrupt* aspects of typical mathematics classroom activity in order to facilitate students' recruitment of meaningful-to-them resources for spatial reasoning (see Ma, 2013). In other words, a key design conjecture was that disruptions to mathematics classroom activity like space, tools, and division of labor would make it difficult for students to depend on familiar means of problem solving. These familiar means included physical tools like paper and pencil, as well as conceptual tools like what certain geometric figures “look like” at paper scale and rules for drawing or constructing triangles and quadrilaterals. For students comfortable with these taken-for-granted tools and practices, the disruption would problematize their tacit understandings and provide opportunities to adapt and invent new tools for similar situations in the WSG setting. For other students, the disruption would release them from the usage of tools and practices that they had trouble reasoning with (but felt they had to make use of them), and so promote their own sense-making and connections to out-of-school experiences and knowledge.

I treat place as not simply containers with physical features, but as constituted by a built environment in interaction with participants' past, ongoing, and anticipated engagements in them (Leander, Phillips, & Taylor, 2010; Lefebvre, 1991). I take an “interactionist” view of embodiment (e.g., Stevens, 2012), treating human cognition and action (and therefore doing and learning mathematics) as distributed across the local semiotic environment, which includes historically and culturally developed tools for sense-making, as well as talk, co-present others, and the material world. Bodies and materials (including the built environment) are fundamental resources for reasoning—not as separate, external elements in support of mental activity, but as constituent components of cognition. As interaction unfolds, embodied, discursive, and material resources are dynamically recruited for meaning-making and communication, in service of the goals of the group. These

semiotic resources mutually elaborate each other; they bring meaning to ongoing interaction, and simultaneously take on particular significance in the context of that ongoing interaction.

## Methods and Data

WSG, implemented as part of a design study, was investigated in two different settings: a 7th grade mathematics classroom at a struggling (by state testing standards) urban middle school (KCMS), and a two-week residential summer enrichment program (SEC) held at a university for high-achieving rising 9th and 10th graders. At KCMS the WSG tasks took place in the school's soccer field, while in SEC students worked in a grassy university quadrangle criss-crossed with concrete walking paths. The study took place over the course of five consecutive weeks at KCMS, and just two days in SEC. Lesson sequences were designed and revised with instructors at each site, in response to ongoing analysis of student engagement. The mathematics coach and classroom teacher were the primary instructors at KCMS, while researchers served as instructors in SEC.

Data collected at both sites included video records of design sessions, interviews with students, field notes during WSG implementation, student work artifacts, still images, and video and audio records of WSG activity. Whenever possible video and still images were recorded from above the students' WSG activity (atop a nearby hill or building) as well as from ground level. This allowed close analysis of embodied engagements using a close-up but narrowly-framed view as well as a wide-angle, bird's-eye-view of entire groups. Methods of analysis began with rough coding of students' recruitment of resources to engage in problem solving, in relation to the designed disruptions of WSG. "Hot spots," or episodes of interest due to an unexpected event, or intense engagement by students, or representativeness of types of student-recruited resources, were chosen and analyzed using methods of multimodal discourse analysis (Norris, 2004) and interaction analysis (Jordan & Henderson, 1995). These findings serve to contribute to theories of (mathematical) bodily engagement in places, and to future design conjectures for leveraging bodies and space as resources for mathematics learning.

## Findings

The WSG tasks moved problem solving to settings where students had a variety of past and ongoing engagements, but never classroom mathematics. The KCMS students spent time on that soccer field over the course of the day either participating in gym class activities or soccer practice and games. At the time, the boys' soccer team was in the midst of a winning season, and most of the students in the class were either on the team or regular spectators. The university quad was often a space that the SEC students had to traverse in order to get between their dorms and the cafeteria and their classes. They also spent some of their free or residential activity time on this lawn, reading in the sun, chatting and gossiping, or playing kickball or capture the flag. These places had vivid associations for the students, and they often engaged in conversations about past or future events while working on WSG tasks. They even made jokes about what would happen if these activities collided: "What if the star striker of the opposing soccer team tripped up on a yardstick we left stuck into the ground?"; "The capture the flag flags better not be the same as these little WSG lawn flags; that would be sad."

Students' bodies, of course, also had rich and varied meanings for the students, and they were deployed from head-to-toe to become parts of inscriptions (e.g., vertices in triangles), as integral parts of the physical representational infrastructure (e.g., holding piece of rope together), as measuring devices (e.g., using a student's height as a unit of measure), and as discursive resources for negotiation of strategies during problem solving (e.g., gesturing, demonstrating, haptically "overhearing" others' actions).

One striking consequence of the WSG setting was that students inevitably incorporated play and playfulness into their work outdoors. This included enacting alternative uses of the various WSG materials (e.g., using a triangle side for jumping rope or tug of war) and telling stories about and partially performing imagined scenarios involving the space and materials (e.g., pretending to be trapped in a quadrilateral). Sometimes play was sustained and intertwined with mathematical activity, while other times problem solving was punctuated with quick episodes of play, constrained by ongoing mathematical engagements. This play was rarely observed in the classroom during instruction before the design experiment began, or when we returned inside to discuss their WSG experiences. Outdoors, play was occasionally a distraction, but often accomplished in parallel to problem solving. On a few occasions play contributed to developing problem solving strategies and innovations.

A second finding of this study was that mathematics activity and problem solving became inextricably tied to *particulars* of bodies, space, and time so that bodies and space were sites of mathematical activity and "environmentally coupled" (Goodwin, 2007) in problem solving. The learning of mathematics concepts and of inscriptions and representational practices co-develop, and are mutually influencing (Lehrer & Lesh, 2003). Here the inscriptional system itself is embedded in a complexly specific place and imbued with meanings, mathematical and otherwise, rather than the very general, very immutable and mobile (Latour, 1990) piece of paper. Inscriptions and inscriptional conventions (for WSG) were developed in relation to past and ongoing bodily engagements in the setting. When it had recently rained, the mud became "ink" for marking off sections of rope, and yardsticks could be pushed into the soft ground as vertices or just for fixing rope in place. Students ran and jumped and danced, often as soon as their feet hit the grass. However, when it was unbearably hot,

students' WSG figures became much smaller in size and their strategies factored in their reluctance to walk across the field. When the field was freshly painted for a game that afternoon, the glaring white lines provided ready-made line segments, right angles, and circles that could be incorporated into representational strategies. Contingencies like these tied the development of students' inscriptional strategies to meaningful local constraints and goals. Space, bodies, and mathematics were produced together for problem solving and learning.

## **Re-Placing Walking in the Analysis of Children's Observational Inquiry**

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Mobility, or people's movement from place to place and through places, is central to learning in everyday life. Social scientists and performance researchers are increasingly using ambulatory methods and walking interviews to examine relationships between place, spatial practices, and knowledge building (Myers, 2011). However, as Taylor and Hall (2013) explain, mobility "is rarely considered part of learning in the learning sciences, and it is almost never used as relevant, experiential content in teaching" (p. 66). In science education there is an increasing interest in place-based and field-based experiences (e.g., Lim & Barton, 2006), however little attention has been given to the role of walking in constituting these experiences or learning science content. In this paper, I focus on the relationship between mobility (i.e., walking), attention, observation and learning about the natural world. I will begin by motivating the need to focus on learning about the natural world and the practice of observation. Then I will describe an exploratory study where I used case studies to examine families' experiences during walks in urban forest preserves (Marin, 2013). I will conclude by discussing how mobile video recordings from this dataset led me to re-conceptualize units of analysis.

### **The Natural World, Culture, and Science Learning**

Learning about the natural world is a central human activity, part of the cultural process of development, and influenced by everyday experiences (e.g., Cajete, 2000). Observation is one methodology used to learn about the natural world and plays a significant role in science teaching and learning in the primary grades and outside of school, particularly in domains that rely on field experiences and investigations (Windschitl, Dvornich, Ryken, Tudor, & Koehler, 2007). In addition, observation is almost always mentioned in reform documents but it receives far less attention than other inquiry practices and is rarely theorized (Smith & Reiser, 2005). Perhaps observation receives so little attention theoretically because it is often viewed as a mundane practice and a simple step in the scientific process. However, some researchers have argued that observation is a complex process and involves the relational activities of watching, listening, and feeling in order to selectively attend to and notice particular features of the environment (Kawagley, 2006). These activities are dependent upon the coordination of theory, domain knowledge, and attention habits (Eberbach & Crowley, 2009).

According to Ingold (2011), "all science depends on observation and all observation depends on participation—that is, on a close coupling, in perception and action, between the observer and those aspects of the world that are the focus of attention" (p. 75). From these perspectives, observational inquiry is rooted in particular places and directly influenced by land and its inhabitants (Kimmerer, 2012), as well as the weather-world or the medium between sky and ground that people inhabit and navigate (Ingold, 2007). Walking is an everyday observing practice that individuals, families, and groups engage in to build relationships with the natural world (e.g., Bang, 2009). As Waitt, Gill, and Head (2009) suggest, walking is a "way of doing nature" (p. 43). Direct experience and participation with nature through the use of one's body and sensory perception is central to doing science and making sense of the environment (e.g., Cajete, 2000). The purpose of this paper is to illustrate the ways in which the practice of observation is constituted by *bodies-in-place*.

### **Investigating the Relationship Between Mobility, Place, and Science Learning**

To examine the relationship between body sense, place, movement, attention, and observation, I asked six families (three Native American families and three non-Native families) with children between the ages of five to eight years old to go on repeated walks in urban, forest preserves. I will refer to this activity as forest walks. In the context of this study, culture, or the routine practices that families engage in to accomplish goals, is enacted or "paced out along the ground" (Ingold & Vergunst, 2008, p. 1). This mobile research activity incorporated the urban, ecological context and afforded an examination of the moment-by-moment process of attention and observation as families traversed land.

The design for this study grew out of my participation in a community-based design research project and my experiences on that project as a designer, teacher, and researcher. The aim of the project was to develop culturally based curriculum for Indigenous youth and families (see Bang et al., 2014). Deeply grounding this work is the belief that humans are not apart from nature but a part of nature and that nature is all around us (Cajete, 2000). A foundational design conjecture of the project was that people learn about the natural world by walking and talking land (Cajete, 2000). I extended the work of this community-based design project by using a more constrained research activity (i.e. forest walks) to examine the ambulatory aspects of learning and

observational inquiry from a place-centered and body-centered lens.

### **Developing Embodied Units of Analysis**

During forest walks, families used two forms of digital technology: a digital camera and the POV 1.5, a wearable camera that continuously captures video (see <http://www.vio-pov.com>). This camera was positioned on the shoulder and captured the embodied experiences of family members while on the walk. Overall, the data corpus consists of over 30 hours of video. Videos of the forest walks were analyzed in Transana v2.51 (Woods & Fassnacht, 2012). Transana pairs transcript and video for analyses purposes and has been successfully used for multi-modal analysis (Halverson, Bass, & Woods, 2012). In each case, I focused on the routine interactional practices families engaged in while walking in order to highlight what is worthy of being noticed. I relied on techniques from conversation analysis (e.g., Pomerantz & Fehr, 1997), ethnomethodology (Stevens, 2010) and microethnography (Phillips, 1983), to identify sequences within each forest walk. Through multiple viewings of video, what became most evident to me was that the activity, or the walk, was demarcated by changes in gait. Working from this point, I developed a unit of analysis, which is bounded by change in gait. I term this unit of analysis *ambulatory sequences*. Once sequences were identified, video clips were created and organized in collections for each participant and coded for sequence components. These sequence components or semiotic fields include physical location, walking patterns, spatial orientation, movement characteristics, and talk. I argue that each ambulatory sequence is complex in nature and akin to a micro or situated activity system (Goodwin, 2003) where action emerges from the layering of fields at the individual and social level.

### **Conclusion**

Mobility is integral to knowledge and meaning making practices (Gutiérrez, 2008; Ingold & Vergunst, 2008). What we attend to with respect to the natural world is organized, at least in part, by people's movement through place. More specifically, walking or making our way from place to place and noticing phenomena in our surroundings is both structured by land and structures our engagement with the natural world. How do we account for and analyze the relationship between mobility, attention, and observation from a systems perspective? Researchers use a variety of techniques to identify routine phases and patterns in interaction. Once concepts of interest are identified, exchanges are often coded at the utterance or turn level. For example, analysts may focus on shifts in discourse in order to identify sequences. In this paper, I introduced two ideas: (a) that change in gait may serve as a marker for sequence boundaries and analytic units and (b) that sequences bounded by change in gait constitute an ambulatory turn. I suggest that families' walks follow a pattern of continuously walking and stopping and that these unique sequences constitute situated activity systems. This unit recognizes the importance of body sense (Cajete, 2000) as a way of knowing the world and considers the layered and emergent qualities of interaction. In addition, it provides a structure to explore relationships between the physical and verbal organization of attention and observation with respect to land.

### **Locative Learning: Constructing Sense-Scapes Through GPS Drawing**

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This paper describes GPS drawing as a sociotechnical, intact activity system (Greeno, 1998) in which two groups of three youth inscribed an image or word over the terrain of their neighborhood by walking a planned route with a handheld Garmin™ GPS device. GPS drawing was part of a larger social design experiment (Gutiérrez, 2008) to support youth in counter-mapping (e.g., Peluso, 1995) their neighborhood, or making claims to community resources for the future with urban planners and local stakeholders (Taylor, 2013; Taylor & Hall, 2013). GPS drawing was a designed activity that brought the sensuous experiences of the body-in-place in contact with mapping technologies to produce a narrative of urban life that is oftentimes ignored (i.e., that of inner city youth). Within this tension—between the practiced and the abstracted—young people constructed “sense-scapes” (Grasseni, 2009), or spatially-indexed narratives of emotion, nostalgia, and morality as a new map layer. While GPS drawing has traditionally been considered a form of “locative media” (e.g., Reiser, 2011) in some fields, I argue that GPS drawing is an example of *locative learning* where youth gained facility with geospatial technologies and mapping practices (e.g., ground-truthing, scale-body translations) while inscribing and sharing new and emergent meaning into an intimately familiar landscape with their mobile bodies.

### **Framing and Design**

How do you describe a place that you know intimately? What are the salient experiences you have in that place? How do you *show* that you know a lot about a place? How can you represent place-based feelings and affect as a legitimate (map) layer of experience? These were the questions I asked when designing GPS drawing as one activity in a series for youth to learn about counter-mapping their neighborhood—a racially segregated food and mobility desert in a midsouth city—with urban planners and local stakeholders.

Having done an ethnographic study of a participatory planning process in the same neighborhood as

this design study, two observations were important for designing the GPS drawing activity in particular. First, residents often treated the map as an invitation for storytelling. Planner-created maps provided entrée into the telling of one's rich history of many lived experiences within that place. These stories served to disrupt the disembodied, abstracted narrative represented on the map to create a *sense-scape* of lived experience and desire. Sense-scapes bring the sensuous experiences of the body forward, but also layer abstracted space with *common* narratives of nostalgia, desire, fear, and morality that give the map personally relevant meaning (Grassani, 2009). The second observation important for designing this activity was that the experiences of young people in the community were oftentimes ignored or misrepresented by both the adults and the maps that were central to the participatory planning process (Taylor & Hall, 2013).

Therefore, GPS drawing was a designed activity to facilitate young people in bringing all of their senses to bear on, not just the map of their neighborhood, but mapping technologies and the neighborhood itself. GPS drawing was a technologically re-mediated way of walking the neighborhood and telling a story about a place in which the young study participants had their own rich histories and experiences. I describe this activity as a sociotechnical intact activity system because individuals, the resources and senses of their bodies, technologies (i.e., GPS devices, pencils, wearable cameras), representations (i.e., maps of the neighborhood), the terrain of the neighborhood, and the resources of that environment came together to pose challenges, solve problems, and inscribe a new layer of meaning over that place.

GPS drawing consisted of four phases and lasted three hours, though experiences from the activity were referenced throughout the remaining weeks of the study. The first phase was a tutorial on GPS drawing that occurred in a local, youth-serving organization located in the neighborhood. The second phase was a planning phase, where study participants in groups planned their inscriptions with markers and maps of the neighborhood. The third phase was the walking/inscribing phase through the neighborhood with maps, GPS devices, and wearable cameras. The fourth and final phase was a sharing/analysis session in a university computer lab where youth's inscriptions were uploaded into Google Earth™ and authors described their production experiences on the ground to each other and adult volunteers and researchers. These inscriptions were also shared with urban planners and local stakeholders a few weeks later as part of the culminating event of the study—an “Open House” youth counter-mapping session.

## Methods and Data

The young people that participated in GPS drawing, and the larger social design experiment, were members of a bicycle-building and riding workshop located in the neighborhood's youth-serving community center. Part of “The Workshop’s” mission was to address issues of youth mobility and access to citywide resources. Local stakeholders in the community were eager to make the neighborhood safer and more conducive to independent mobility for youth, either on foot or on bicycles. Carissa, Leah, Beth, Fred, William, and Wallace were all African-American youth between the ages of 12 and 15 years old (1). Designed activities took place over five weeks in The Workshop, through the neighborhood, or in the university computer lab. We met twice a week. GPS drawing occurred in the third week of the study; youth made other artifacts with mapping technologies during other sessions. After the five weeks of designed activities concluded, the youth met with professional cartographers and urban planners to argue for changes in the community, displaying their artifacts as evidence for “on the ground” research and analysis.

Over the course of the study, my research team and I made video records of all the activities. I also conducted initial and concluding interviews with each participant. I collected participant-produced artifacts that included time-diaries, GPS tracks of their mobility around their homes using a GPS data logger, and photos and camera footage. For GPS drawing specifically, the activity was video recorded by two research team members, and was also captured by participants who were wearing head cameras while they participated in the activity.

## Findings

Constructing technologically mediated sense-scapes over the map of their neighborhood came easily to the youth. The boys walked the shape of an hour-glass with sand/time dripping through it over the baseball field adjacent to their school; the girls inscribed the word “LOVE” over a five-block area that included all of their homes. For each group, the walk through the neighborhood was dense with talk and stories. Topics included, but were not limited to, cicadas, the lack of sidewalks, being hot, the rain, music videos, cute boys living in the neighborhood, bad drivers, a girl in “booty shorts,” and dozens more. But from my analysis, the paths they created on foot were more than *story* lines. These pathways held their bodies together in coordinated activity with technology, elevated their pulses, fleetingly brought neighborhood residents into the interaction, sent them careening down hills on their bottoms, and elicited reactions from all the senses (even taste). Even though the mobility of the “scribe,” or the person wearing the GPS device, was the only mobility that *actually* mattered for the inscription, all of the teens walked the planned routes together. Neither group decided to send the scribe down a dangerous, slippery slope alone or walk up a steep hill while the others took a different route. These

newly intentioned, collaborative pathways through a familiar landscape became *lifelines*—whole bodies were engaged and held intact within and because of a place already teeming with action, memories, and sensation.

Compared to the (literal) liveliness of the planning and production phases of GPS drawing, the analysis phase seemed void of life. Once viewable on the overhead projector in the computer lab, the lifelines that emerged on the ground (sadly, to me) transformed into a litany of errors and *inaccuracies* for the youth. Leah, someone prone to elaborate, embodied dramatizations, no longer enthusiastically used her body to respond to adult queries and lead conversation; seated at a desk, she obsessed over the errors that the GPS device left in the record of their movement with a deflated tone. Even though the word “love” was easily visible (and I would argue, beautifully done), both Leah and Carissa were hyper critical of their inscription. While the girls wanted to express in the GPS drawing the love they felt for their neighborhood, they felt very little of that toward the device itself in the viewing phase. The layering of stories, feeling, memory, embodied responses, collaboration, and group cohesion that existed on the ground was reduced to a critical self and technological appraisal of performance, as viewable and measurable by the track data on top of a satellite image of the neighborhood. In this way, the vibrancy, at the *scale of doing*—of bodies intersecting with an important place—all but vanished at the *scale of viewing*, where place-making and technological production became another school-ish exercise of doing well on an assignment. The disparity of youth engagement between the scale of doing and the scale of viewing the inscription shows that locative learning has enormous potential for fostering the kinds of ideal learning for which we design—relevant, collaborative, creative, and interest-driven. This disparity also demonstrates that the context and norms of a classroom setting (in this case a computer lab) have disciplined youth to make even the most novel activities feel like school.

## **Re-Placing Bodies Across Imaginative Geographies In Classroom Activities With Map Argument Performances**

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This paper identifies findings related to bodies-in-place from a design study in classroom settings investigating the teaching and learning of the interpretation and production of thematic maps and map argument performances with young people. Two iterations of a design experiment investigated how map performance activities supported learning in innovative ways, primarily through media production with small groups of young people.

### **Framing and Design**

*Map performances* are practices that involve people in interaction with *thematic maps* and *map argument performances*. Thematic maps are maps that show the spatial distribution of a concept or phenomenon. They were first produced in the mid-1800s in the United States, but we know very little about how they are interpreted, understood, and read by those who use them (Wiegand, 2003). What I call map argument performances are a new category of practices; they are segments of news or other media produced to make arguments or tell stories that include bodies and thematic maps in interaction. The term is meant to cover bodies that might be heard (e.g., a voice over accompanying a complex thematic map on television news or on the Internet) and/or seen. New forms of map argument performances have been developed within the last few years. For example, since 2008, political news analysis on the U.S. television news network CNN regularly includes use of a “magic map,” a multi-touch interactive screen in which CNN analysts change map scale (e.g., from county-level to state-level election results) and data layers (e.g., moving from previous election results in a state to current polling) while quickly making arguments and predictions regarding upcoming elections.

Both thematic maps and map argument performances are increasingly prevalent in media streams intended for adults and for youth. And while media producers create and distribute complex maps and map argument performances with increasing regularity, there is no effort, even in K-12 schooling, to support viewers in learning how to read these texts. Advances in technology and easy access to large public data sets have also meant that people with little or no technical training using free online computer applications can create complex thematic maps and map argument performances.

Map performance practices include interpreting, playing with, remixing, and creating thematic maps and media presentations with thematic maps and people in interaction. Any interaction of a person and a thematic map will involve map performances. But map performances can also be leveraged as activities in instructional settings to support young people in learning to interpret and produce thematic maps and map argument performances. This paper reports on a study of the ways in which map performance activities supported learning in innovative ways, primarily through media production with small groups of young people in classroom settings. Map performance activities for the classroom design experiments conducted during this study were informed by prior research I conducted analyzing map performance activities as texts utilizing analytic perspectives from multimodality within literacy studies (e.g., Kress & van Leeuwen, 2001), historical and critical cartography (e.g., Crampton & Krygier, 2006), and media literacy (e.g., Buckingham, 2003).

## Methods and Data

I report here on data collected from two iterations of a design experiment (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). While little is known about the teaching and learning of thematic map interpretation generally (Wiegand, 2003), pedagogies of map performance activities have not yet been studied at all. The purpose of the design experiment is to investigate teaching and learning with map performance activities in classroom settings. The first iteration was conducted during a Summer Enrichment Course (SEC; all settings and participants are described here with pseudonyms) devoted to spatial thinking. Participating in the class were 12 students, all rising ninth and 10th graders, who lived in university on-campus housing at a large urban university in the United States for two weeks. The course included 54 total hours of instructional time across multiple facets of spatial thinking. The data I collected related to map performance activities comprised approximately 7 hours of instructional time. The second iteration of the design experiment took place in three media production classes taught by the same teacher at Local County High School (LCHS), a large suburban public high school in the Southeastern United States. Each of the media production classes had 25 students and each had one grade level of students: one class each for 10th, 11th, and 12th graders.

In this paper, I focus analysis on student participation in two designed activities from SEC and LCHS: the *John King Remix* activity and the *Make Your Own MAP* activity. Students participated in both activities in small groups (4-5 students). Following are brief task descriptions for each of these activities: In the John King Remix activity, students recorded a new audio track to plausibly match video footage from an 89-second clip of CNN political analyst John King conducting analysis at the magic map prior to the 2008 U.S. presidential elections. In the Make Your Own Map Argument Performance (MAP) activity, students created their own magic map segment similar to CNN magic map segments described above. In groups, students made an argument in front of a set of maps in the style of John King doing political analysis with the magic map. Students first created maps to be used in the segment and then performed the segment with two “on-camera” personalities: one student in the role of John King and another student in the role of Wolf Blitzer.

Data collected were video and audio records of all phases of instruction and student work, interviews with student work groups, artifacts of student work and final productions, and interviews with the teacher at LCHS.

## Findings

This paper makes two claims relative to bodies-in-place: (a) new meanings and new identities are formed among maps and group members during the John King Remix and (b) technologies in the Make Your Own MAP provided resources for embodied performances of identities and global and local spatial stories. Both claims relate to “the construction of difference in terms of the interrelatedness of spaces and histories of travel as they are connected to the moment of the present” (de Haan & Leander, 2011, p. 323). That is, in both designed activities reported here, participants formed and reformed their own racial, ethnic, and cultural identities and the identities of others across the physical and social space of the room as well as across the *imaginative geographies* (e.g., Gregory, 1995) of local and distant others represented on the maps and map performances that were the contested and central texts of the activities.

The first claim is that in the John King Remix, resources for textual reinterpretation in the form of a remix made possible embodied improvisational engagement with co-participants such that reading the map together and recreating the map together became a way of forming new meanings and making new identities both of the map argument performance and for co-participants. The clearly performative nature of the interactions of participants, the ways that they jumped into spaces of improvisation and embodiment as they produced a new vocal track for a segment of political analysis at CNN’s magic map were invited and supported by an activity that specifically tasked them with remixing a performance that included John King’s movements and vocal performance as resources. In these interactions, the collection of map symbols, traces, gestures, gaze, body movement, vocal registers, popular culture references and practices, thematic data layers, media personalities’ words, paper script, and embodied improvisational play positioned bodies, ideologies, and cultural practices against one another to form new meanings or make new identities—new bodies in new places.

The second claim is that in the Make Your Own MAP activity, technologies provided resources for participants to spatialize and other co-present bodies. Unlike other activity systems—even those with thematic maps such as the John King Remix—the Make Your Own MAP uniquely made possible the performance of localized *geo-bodies* (adapted from Winichakul, 1994)—spatialized, othered bodies of co-present participants. For example, “Mexican-born residents of Texas” was a demographic layer added to a map being created by one group via mapmaking software. As this group’s members worked, this data layer on the computer was seen as extending out to Vincent, a student who was sitting nearby. For group members, his identity as a Mexican-American was foregrounded and they began to talk with him about his family heritage. This demographic layering made possible the spatializing and othering of nearby bodies like Vincent’s, recruiting performed identities that were used in spatial stories of difference and sameness. The unique aspect of the geo-body performance via the technologies designed in the Make Your Own MAP is the way in which data layers came to

adopt, for learners, abstract and concrete resources of sameness and difference nearby for the performing of global and local spatial stories and identity constructions by youth—new bodies in old places.

## Endnotes

- (1) All participant, place, and organization names are either pseudonyms or intentionally vague.

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# **Connecting Learning and Becoming: Studying Epistemologies and Identities as Interconnected, Dynamic Systems**

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**Abstract:** This symposium brings together researchers from different countries, research disciplines and theoretical orientations, all of whom are engaged in the empirical study of connections between epistemologies and identities in educational settings. By comparing and contrasting their conceptions, methods and findings we seek to identify common themes and challenges, on the basis of which learning scientists might develop a more coordinated agenda for future research. Specifically, we propose to examine the timescales of processes studied, researchers' assumptions about the conceptual relations between epistemologies and identities, and the extent to which particular kinds of interaction between epistemologies and identities are local or universal.

## **Background**

A growing body of research suggests that people's epistemological beliefs are related to their conceptions of themselves as individuals and as participants in communities (e.g., Gottlieb 2007; Herrenkohl & Mertl, 2011; Packer & Goicoechea, 2000; Wortham, 2006). However, the nature of these relations remains unclear. There are several reasons for this. First, few studies have focused explicitly on investigating the relations between identities and epistemologies. More often, evidence of such connections has been a byproduct of studies focused on other matters. Second, researchers of identity and epistemology come from a wide variety of disciplines and theoretical orientations, and rarely agree on operational definitions or methods of data collection and analysis. Accordingly, much of what research can currently tell us about how epistemologies and identities are related is either exceedingly vague or highly theory-laden.

The aim of this symposium is to begin an inter-disciplinary conversation about how learning scientists might study the relations between identity and epistemology in ways more conducive to building a body of cumulative knowledge and to guiding educational practice. We seek to do this by bringing together researchers from different countries, research disciplines and theoretical orientations, all of whom are engaged in the empirical study of connections between epistemologies and identities in educational settings. By comparing and contrasting conceptions, methods and findings from these different research programs, we hope to generate insights into common themes and challenges, on the basis of which learning scientists could develop a more coordinated agenda for future research.

Following outlines below of the four papers to be presented in the symposium, we suggest three themes on which the discussion might focus.

## **Heterogeneous Resources for Ontological Learning**

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The social and natural worlds provide heterogeneous resources that contribute to learning and to pathways across which people are constituted. In order to account for the learning pathways that any individual travels, analysts must determine which configurations of resources become relevant in a given case. Out of the many resources that might be relevant to constituting an individual, a few generally become salient. We illustrate this contingent process by describing one young Mexican migrant in the U.S., sketching relevant aspects of family interactions, educational practices, local community characteristics and national discourses. This girl, her family, and other actors combine heterogeneous resources in contingent ways as they establish an emerging pathway across which she becomes a "good reader."

As established by significant bodies of work, learning is not just a matter of accumulating knowledge. Learning is ontological, in the sense that learners become different kinds of people as they learn. Just learning a certain type of knowledge or skill does not in itself determine the type of person a learner becomes, however. Across a pathway of events, people draw on various resources in constituting the learner as a person. What resources contribute to this constitution of persons through learning? How do we determine, in any given case, which of many potentially relevant resources are in fact crucial in constituting the person?

This paper addresses these questions, using an example of one immigrant girl (“Allie”) as she becomes a “good reader.” How do we know which of the various potentially relevant resources in fact contribute to Allie’s emerging personhood as she becomes a good reader? In accounting for any focal object or process, like Allie becoming a good reader, many resources could be relevant. Many resources are potentially relevant to Allie’s case. For example, over a timescale of two centuries Mexico and the United States have developed a complex, hierarchical relationship, which has led to migration policies and economic conditions that lead some Mexicans to risk traveling without documents, and this has yielded stereotypes of Mexicans as less likely to succeed. Over a timescale of two decades, recent Mexican migration to areas of the U.S. that have not traditionally been home to Latinos has yielded more flexibility for migrants, because longstanding residents unfamiliar with Latinos less often apply entrenched stereotypes and thus sometimes give immigrants more space for self-definition.

The town where Allie lives has a distinctive history of immigration, such that it is more welcoming toward immigrants than many others. Over a timescale of one decade, Allie’s family has developed its own history of migration, and Allie’s ontogenetic trajectory differs from that of many children in similar circumstances. It is relatively easy to imagine how these foregoing resources or processes might be relevant to Allie’s personhood as she becomes a good reader. But many other potentially relevant resources exist. For example, Spanish and English differ in their grammatical encoding of motion. Given that Allie speaks English and Spanish, this might be relevant, but it does not in fact seem to account for important aspects of her social identification in the same way as the previous ones. How do we rule out such potentially relevant resources, determining that they do not in fact contribute to a focal process or phenomenon?

In this paper we draw on Silverstein (1992, 1993), Agha (2007), and Latour (2005) to answer this question. Silverstein (1993) and Agha (2007) provide general accounts of how relevant context is established for social identification within and across events, as people mobilize heterogeneous resources from various scales by deploying signs that point to relevant context and help constitute some focal object or process. Latour (2005) complements this account in useful ways, providing a comprehensive account of how heterogeneous resources in a network together make social identification and other processes possible. He argues that the social world is constructed out of heterogeneous “assemblages.” For any focal phenomenon a “network” has been constructed, and this network is heterogeneous in both scale and type. Ideas, objects, and dispositions from different scales are brought together.

In Allie’s case, as illustrated below, it matters that she grows up in a town of the New Latino Diaspora, where stances toward Latino migrants are less entrenched than in areas of traditional Latino settlement. It also matters that she is Mexican and not some other nationality, because of the history of Mexican migrants in the U.S. over the past century and associated models of Mexicanness. These two patterns, as well as others described below, form part of the network of heterogeneous resources relevant to constituting Allie’s emerging personhood, despite the fact that they have themselves emerged over very different spatial and temporal scales (the New Latino Diaspora over the past twenty years and models of Mexicanness in the U.S. over at least two centuries). A network is also heterogeneous in type. Material objects matter, like the spatial and educational segregation of residents in Allie’s town and the resources like books available to children from different groups. Ideas matter, like the models of personhood circulated in the media that represent Mexicans in certain ways. And embodied dispositions matter, like the pleasure Allie takes in reading a book and her facility in conversations about text.

In Allie’s case, we argue that these particular resources are relevant to the person that she becomes as she learns to be a good reader, while many other potentially relevant ones (e.g., facts about English and Spanish verbs) are not. Latour argues that no particular process, scale, or resource is always relevant. Even though the New Latino Diaspora and the flexibility offered there is important to Allie, this particular context or resource will not be important to every Mexican student in Allie’s town. Some of her peers travel pathways similar to those established by Latino children in areas of traditional Latino settlement. Social analysts should not “limit in advance the shape, size, heterogeneity, and combination of associations” in the network (Latour 2005:11). We must account for how, in a given case, a heterogeneous group of resources is assembled in a contingent way and becomes the relevant network to account for a focal process. In our case, the configuration of resources most salient for Allie forms a relatively distinctive network. Our job as analysts is to describe the network of resources that become relevant to a focal case or class of cases. Different cases will have somewhat different configurations of resources that account for the person that a learner is becoming. Analysts must avoid one-size-fits-all theories that limit relevant resources to only a few pre-established ones. We must instead do the detailed empirical work required to trace the networks of resources that matter in particular.

## **Disentangling Identity and Epistemology to Study How They're Connected**

Eli Gottlieb, Mandel Leadership Institute

Broadly speaking, an identity can be defined as the conception one has of oneself as a person. Under the influence of Erikson's seminal writings on the topic (e.g., Erikson, 1968), psychologists have traditionally conceived of identity development as a process of reconciling and choosing between competing self-descriptions. Individuals who have arrived at a coherent, integrated conception of self after a moratorium period of actively "trying on" and choosing between competing self-descriptions are considered to have achieved a mature identity. Those who have avoided such choices, or whose self-descriptions are inconsistent and unstable, are considered to possess foreclosed and diffuse identities, respectively (see, e.g., Marcia, 1966).

Whereas an identity is a conception one has of oneself as person, an epistemology is a conception one has of knowledge – what knowledge is, how it is acquired, and how it is justified. Psychologists have conceived of epistemic development as a process of coordinating the objective and subjective aspects of knowing (see, e.g., Hofer & Pintrich, 1997; Kuhn, Cheney & Weinstock, 2000). At first, the objective dominates and all knowledge claims are assumed to be conclusively verifiable (absolutism). Subsequently, the subjective dominates and knowledge claims are treated as expressions of mere personal preference (multiplism). Finally, a balance is achieved in which neither aspect dominates and knowledge is seen as something that is constructed tentatively by evaluating evidence for and against competing points of view (evaluativism).

A growing body of evidence suggests that identity achievement is associated with evaluativism, moratorium with multiplism, and foreclosure with absolutism (see, e.g., Boyes & Chandler, 1992; Krettenauer, 2005). These associations make theoretical sense, for the reconciliation of competing self-descriptions can be seen as a special case of the general activity of reconciling competing points of view. On the basis of such connections, psychologists have proposed that epistemic development constrains identity formation. Yet the reverse might also or instead be true, namely, that identity formation constrains epistemic development.

I have presented elsewhere (e.g., Gottlieb, 2007; Gottlieb & Wineburg, 2012) various empirical examples in which a research participant's sense of himself as a person determined the epistemic stance he adopted to a given controversy or cognitive task. I presented one such case in an interview study I conducted in religious and secular schools in Israel to investigate how children and adolescents justify their religious beliefs (Gottlieb, 2007). In that study, I reported on the responses of Shlomo, a twelfth-grader at a religious school, to successive, differently formulated questions about whether his belief in God might be mistaken. His pattern of responses showed that, though he was keenly aware that God might, in fact, not exist, he was not prepared to admit that possibility – to the researcher or to himself. In a more recent study (Gottlieb & Wineburg, 2012), we presented additional cases of people's identities shaping their epistemologies. Specifically, we showed that even professors of history – who are highly trained readers of historical documents, and expert users of a variety of sophisticated epistemological tools to assess provenance and credibility – move with great ease and comfort between reading as a critical investigator and reading as a committed community member who considers critique inappropriate. In other words, in both these studies we found evidence of people adapting their epistemologies to fit their identities, rather than the other way around.

However, the question of how epistemic development and identity formation are related is not only an empirical question. It is a conceptual and methodological one too (cf. Chinn, Buckland & Samarapungavan, 2011; Greene, Azevedo & Torney-Purta, 2008). The extent to which these processes are found to overlap or constrain one another will depend on how each construct is defined and measured. Because many, commonly used measures (e.g., Harter, 1999; Marcia, 1966; Schraw, Bendixen, & Dunkle, 2002) were developed without connections between epistemology and identity explicitly in mind, they include several elements that are ambiguously situated in a gray area between epistemology and identity.

In this paper I review some of these instruments and pick out three causes for methodological concern: construct validity, a focus on the products of identity negotiation and epistemological reflection rather than on the processes thereof, and cultural insensitivity. I conclude with suggestions of how to address these concerns. In particular, I recommend methods that observe people engaging actively in identity negotiation and epistemological reflection as opposed to recording self-reports after the fact. In addition, I argue for measures that are comparative, not only across age groups but also across social contexts.

## **The Relationship between Expertise and Interest in Science Learning**

Leslie Rupert Herrenkohl, University of Washington

This presentation will make a case for a broad view of learning by building a model that addresses the interconnections between interest, identity, and expertise using the work of Holland, Skinner, Lachicotte, & Cain (1998) as a starting point. Building on my recent book (Herrenkohl & Mertl, 2011), two case studies will explore how this model plays out in one classroom of racially, ethnically, linguistically, and socioeconomically diverse fourth graders and their science teacher. Data collection took place in a public science{ XE "science" }

and technology magnet school situated in the poorest quadrant of a Northeastern US city. Approximately eight hundred children attended the school. As a neighborhood magnet school, it welcomed children who lived in the neighborhood and also served students from throughout the city as part of a voluntary de-isolation plan. In 35 classrooms from preschool through grade 6, about half of the students were children of color. About one quarter attended a Spanish bilingual program at the school. Approximately ninety percent of the students qualified for free or reduced lunch. At the time of the study the school had been in operation almost two years.

Data included videotapes and transcripts of classroom discussions in whole group and small group lessons as well as audiotapes and transcripts of interviews with students and the teacher. Each case study analyzes how a particular student interacted with others over time to improvise his or her own experience and contribute to the creation of the cultural resources within the classroom community. I trace how each student developed and refined interests, identities, motivations, affective orientations toward learning, and personal and social values about what is worth learning and if, how, and why one ought to put certain knowledge and skills into practice.

The two focal cases provide different entry points to understanding the relationship between identity and epistemological and conceptual expertise. Over the course of the study, Raul's confidence and ability to explain his ideas served as a basis for improvisation within new classroom values and practices. He was instrumental in creating joint understanding of key terms, epistemological practices, and concepts. He also took others' perspectives to help the class discuss conceptual and semantic sticking points. Christie, on the other hand, began the study lacking confidence and was in the bottom three questioners in the classroom, yet she experienced one of the most dramatic personal transformations. Over the course of the study, Christie went from assuming a defensive, resistant posture to a more confident engaged approach, developing stronger epistemological and conceptual understandings and developing a stronger identity as a capable student in science. These cases present a different view of how the "same" classroom was experienced for each student. Each student created, along with their other classmates and teacher, opportunities for students in the classroom to experience, own and exercise new ways of being, knowing, and doing science together as a class. Theoretical and practical implications of examining interest, identity, and expertise together to account for learning will be discussed.

## **Learning and Becoming in Practice: Constitution, and Learning to Be Muisca**

Martin Packer and Martha Rocío Gonzalez, University of the Andes, Bogotá

In this presentation we will propose that the focus of ICLS 2014 on "learning and becoming" should be understood as a call to focus on *constitution*. Elsewhere we have argued that educational research in general can and should become a science of constitution (Packer, 2010), and the same argument applies to the Learning Sciences in particular.

Scientific explanation is generally assumed to take causal form, but in fact all sciences search for both causal explanations and *constitutive explanations*. The term "constitution" has become widely used in the social sciences but has rarely been defined with precision. We will build on recent work in the philosophy of science that has clarified the nature of constitutive explanation, as distinct from but equal to causal explanation. Causal explanations assume that two entities or events are independent of each other, that the cause precedes the effect in time, and that if the cause had not occurred the effect would not have occurred.

Constitutive explanations, in contrast, deal with entities or phenomena in which a whole is made up of parts, as a system with several levels of organization. Constitutive explanations answer questions about what something is, and how it comes to be. They account for the properties of phenomena by reference to the structures, or systems, in which they exist. The relationship between part and whole is a symmetrical and reversible relationship: a whole is constituted by the organized activities of its parts; a change in the parts is manifest as a change in the whole; and a change in the whole is also a change in some or all of its component parts.

Both natural sciences and social sciences ask (and answer) both kinds of question, causal and constitutive, but the role of constitutive questions has been largely ignored. Sometimes it has been suggested that causal accounts provide explanations while constitutive accounts provide only descriptions, but this is inaccurate: accounts of constitution are also explanations; they explain the characteristics of a phenomenon by describing a structure in virtue of which those capacities exist (Craver & Bechtel, 2007; Van der Smagt, 2006; Wendt, 1998).

For example, in a microwave oven high frequency electromagnetic radiation *causes* the water molecules in food to vibrate more rapidly. This vibration *constitutes* heat. The vibration is described on one, microscopic, level of observation and description, while heat is described on a second, more everyday, level. We explain their relationship when we say that "molecular vibration constitutes heat."

What, then, might be the form of constitutive explanations in the Learning Sciences, and what would be the consequences of a focus on constitution?

The Learning Sciences have been defined as the study of teaching, learning and development in settings outside the laboratory. When the influence of setting is treated as causal it is presumed that setting and psychology are separate; that there are human psychological characteristics upon which setting then operates. Setting is assumed to be the cause of variations among human psychological characteristics. When, however, we treat the role of context in human psychology as constitutive, we are suggesting that human psychological functions can be best understood as aspects of setting; that they would not exist if it were not for the setting, and that setting and psychology should be described as two separable levels.

We have argued that a sociocultural approach to educational research requires a nondualistic ontology: it must assume that a scientific study of ‘the mental’ as a material phenomenon is possible (Packer & Goicoechea, 2000). This follows the lead of Vygotsky, who based his proposal for a revolutionary new cultural-historical psychology on his diagnosis of dualism as the root of a crisis in the discipline of psychology, and argued that the way forward was to resolve this dualism by the radical move of cutting away idealistic approaches and advancing materialist approaches (Vygotsky, 1927/1997).

This amounts to what has been called a “radical realism,” in which “there are not two worlds [mental and material] that must somehow be shown to be connected by the ingenuity of philosophers, but one: the subject is located in objective reality” (Bakhurst, 1991, p. 115-6). In this analysis, humans are enmeshed in a material and social world. Each of us is thrown into a world that predates our existence and that offers possible ways to be. By participating in a form of life we become skilled in the methods by which it is sustained, primarily through embodied expertise and *habitus*. Our primary way of understanding both ourselves and the entities we deal with is a practical grasp of the possibilities in social practices. In interaction with others - interaction that is fundamentally negotiated and improvised rather than governed by rules or roles - we continually renew the order of a form of life. One can distinguish, consequently, three interrelated aspects of constitution: the order of a form of life, the work of ordering by which that order is produced and reproduced, and the formation of the orderers, the participants who continually carry out this work.

We will illustrate these rather abstract points by describing a study currently undertaken by one of my students. The *Muisca* were the indigenous people living, when the Spanish conquistadors arrived, in a territory of 18,000 square miles centered on what is currently Bogotá, Colombia. They had an advanced civilization, with a confederation of states, an economy based on agriculture, mining, metalworking and manufacturing, and a sophisticated worldview. They have been declared a “lost civilization,” their language “extinct.” A 1943 census recorded only 525 surviving members.

Since 1989, however, a process of reconstruction of the *Muisca* people has been taking place. Key to this reconstruction is the creation of kindergartens in which children will learn again how to *be Muisca*. To study this process of constitution we are conducting research in one of the three kindergartens, documenting the educational practices in which the explicit focus is not only knowing but also becoming.

Any such educational curriculum faces a chicken and egg problem. How to bootstrap the recreation, the reconstitution, of a culture, a way of life, a way of being, that has largely been forgotten? Consequently, our project is a collaborative one: we are keen to avoid the risks and costs of colonialist research design; we intend that our findings will contribute to the ongoing design of instructional practices. The question, “*¿Cómo ser Muisca?*” (“How to be *Muisca*?”), is both our research question and the practical concern that guides everyday practice in the institution (an application of “Sacks’ gloss”; Garfinkel & Wieder, 1970).

This might sound like a concern with “identity,” but we consider this concept to be inappropriate for children of preschool age. Instead we are viewing kindergarten practices through the conceptual lens of a semiotic ontology (Kockelman, 2005; 2010), in which ontogenesis is a matter of deepening levels of semiosis: interpretation of signs as affordances, instruments, conventional actions, and enacted roles. Children learn the culturally appropriate ways to employ material artifacts (such as a drum), the sanctioned forms of action in conventional situations (such as a greeting), the rules and laws that govern enactment of a social status (such as elder), and so on. These are levels of residence, of a way of being in the world, that together constitute a modern *Muisca*.

## Themes for Discussion

Three themes in particular seem to stand out as fruitful starting points for comparison between these studies. The first such theme is timescales. As Wortham and Rhodes note in their contribution above, there are many resources that are potentially relevant to making a person who she is. But to determine which of these resources is more or less crucial to her becoming who she is in particular, we need to consider her participation in processes of various timescales. In Wortham and Rhodes’s study, these include processes of Mexican-US relations that take place over centuries and practices of segregation and differential allocation of resources that take place in a particular town over several years. In Herrenkohl’s study, on the other hand, the timescale is a single school year, over the course of which different students respond differently to the “same” classroom resources and develop distinctive ways of being and knowing. To develop a more coordinated agenda for studying connections between identities and epistemologies, we need to ask ourselves which timescales are most

relevant to the kinds of learning we seek to foster, and which kinds of research design have greatest potential to elucidate interactions between learning and becoming that take place at different timescales.

A second theme is the conceptual relations between identities and epistemologies. Packer and Gonzalez appear to argue for a view of identities and epistemologies as constitutive of one another, or at least for the view that they are both aspects of what it means to participate in a particular form of life. Gottlieb, on the other hand, argues that epistemologies and identities are conceptually distinct. While he allows that, in practice, they are often related to one another in a variety of important ways, he insists that these relations are contingent rather than necessary. Neither Herrenkohl nor Wortham and Rhodes address these conceptual relations explicitly in their papers. However, the research questions they pursue and the ways in which they report their findings suggest that each of them considers the relations between identity and epistemology to combine elements of constitution with elements of causality. A more detailed elaboration of these positions and the identification of key areas of agreement and disagreement between them is another goal of the symposium. This discussion is unlikely to produce a common conceptual framework on which all learning scientists can agree. However, it should provide researchers with a more finely tuned vocabulary and an initial mapping of positions that can help set future studies of relations between identities and epistemologies on a more explicit and coherent conceptual footing.

A third theme is the local nature of identities and epistemologies, and the corresponding variety of interactions between them. Each of the papers in the symposium reports on empirical studies conducted in and around formal educational settings. Yet, each of these educational settings is itself situated within a distinctive cultural, linguistic and instructional ecology. Between Muisca kindergartens in Colombia, religious high schools in Israel, and ethnically diverse public schools on the east and west coasts of the United States, great differences exist in the language, traditions, and cultural expectations governing what it means to learn and to become a person. By discussing relations between identities and epistemologies against this backdrop of cultural diversity, we hope to gain insight into which features of these relations are local and culture-specific, and which features recur across cultures.

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# Toward an Argumentative Grammar for Socio-Cultural/Cultural-Historical Activity Approaches to Design Research

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**Abstract:** This symposium will introduce and illustrate the Socio-cultural/CHAT family of approaches to Design Research. Design Research has become central to the Learning Sciences. It is a key strategy for the study of learning in settings outside the laboratory, and it embodies the twin goals building theoretical knowledge about learning and contributing to educational practice. The contributors to this symposium will argue, however, that Design Researchers need to be aware that they are designing artificial settings in which to study culturally constituted, not biologically-given, processes of learning. The ‘argumentative grammar’ of socio-cultural/CHAT Design Research will be outlined.

## Overview of Symposium

Design Research (DR) has become central to the Learning Sciences. It is a key strategy for the study of learning in settings outside the laboratory. It embodies the twin goals of the Learning Sciences: to build theoretical knowledge about learning, and to contribute to educational practices, broadly defined. Drawing upon theoretical traditions in cognitive science that trace a common genealogy to the work of Herbert Simon. Learning Sciences researchers have been at the forefront of testing and refining educational designs primarily in the artificial settings of school-based classrooms.

One might say, however, that contemporary DR in the Learning Sciences takes the form of designing artificial settings in which to study processes of learning that are themselves assumed to be natural properties of humans: perception, memory, attention, and learning itself. The contributors to this symposium will argue that Design Researchers need to be aware that they are designing artificial settings in which to study culturally constituted, not biologically-given, processes of learning. All the contributors take the position that learning is a culturally-mediated activity, not a purely natural process.

This symposium will present several examples of a family of approaches to DR that we believe holds promise for informing Learning Sciences in this burgeoning area of research and theory. We refer to this family as “Socio-cultural” and “Cultural-historical activity theoretical” (CHAT). The family members share an interest in theories and methodologies that grew to prominence in Russia in the latter half of the 20th century and that have found many adherents in contemporary approaches to learning and development, concerns that are central to Learning Sciences. These approaches, taken as a whole, emphasize the cultural and institutional organization of human action in various forms, in a wide variety of social settings ranging from classrooms in schools to community settings and workplaces. Demonstrating the power of this family of approaches is a central goal of the symposium.

It has been argued that DR requires an “argumentative grammar,” an explicit and clear logic for its research methodology (Kelly, 2004). The papers in this session will articulate an argumentative grammar for socio-cultural/CHAT Design Research, in terms of four issues: (1) defining the unit of analysis, (2) conceptualization of change, (3) kind of explanation sought, and (4) what counts as evidence.

Because of the variety among Socio-cultural/CHAT Design Researchers, the contributors were each asked to take up a common set of questions as a means of encouraging a shared focus.

1. How are theory, methodology, and praxis linked in your approach to design?
2. Who designs in the work you do?
3. How is design bounded by the *object of activity*?

4. Under what conditions does design activity produce new forms of activity and expanded agency, and for whom?
5. What generalizes in design, and how?

## A Fresh Perspective on Design Research: The Science of the Doubly Artificial

Michael Cole, University of California San Diego; Martin Packer, University of the Andes Bogotá

Herbert Simon noted that “The world we live in today is much more a man-made, or artificial, world than it is a natural world. Almost every element in our environment shows evidence of human artifice” (Simon, 1996, p. 2). Artifacts, he pointed out, do not violate laws of nature, but they are aspects of nature adapted to human goals and purposes. The natural sciences seek knowledge about natural phenomena; we ought to call, then, a science that seeks knowledge about artifacts an “artificial science.”

Simon defined information processing systems as “artificial” in the sense that they adapt to complex environments, “as though they were deliberately designed to fit those environments (as indeed they sometimes are)” (Simon, 1980, p. 33). Cognitive science, it followed, was a “science of the artificial.” Like engineering, medicine, business and architecture it was concerned with the contingent rather than with the necessary; with things not simply as they are but as how they might be. Simon provocatively defined design in these terms: “Everyone designs who devises courses of action aimed at changing existing situations into preferred ones” (p. 111).

Alan Collins subsequently suggested that “a design science of education must determine how different designs of learning environments contribute to learning, cooperation, motivation, etc.” (Collins, 1992, p. 15). For Ann Brown, too, design experiments involve “engineering” the classroom while simultaneously conducting experimentation. DR in education is “modeled on the procedures of design sciences such as aeronautics and artificial intelligence” (Brown, 1992, p. 141).

Despite Simon’s insights into the importance of the artificial, however, design research in the Learning Sciences has mainly taken the form of creating artificial environments while the phenomena within it are assumed to be natural properties of human organisms: sensation, attention, perception, and learning processes themselves. Our own perspective, in contrast, offers a different way to advance Simon’s original insight. The classroom is already an artificial environment designed to bring about specific kinds of transformations in the students and teachers who act within it, before researchers arrive. In this sense, the behavior of those students and teachers is itself artificial; teaching and learning are not merely natural processes but are cultural activities that are the product of human design. That is to say, teaching and learning are not the results of fixed and universal psychological processes, but the purposeful consequences of particular local and temporally bounded practices that employ the material artifacts of their environment in order to create, to constitute, specific functional systems of psychological processes. Classroom teaching and learning has always already been designed, albeit sometimes in a tacit, unexamined fashion, or “old fashioned” manner.

From this viewpoint, Simon was correct that human psychological functioning is artificial in the sense that it is the result of adaptation to a contingent environment (though we would not agree with his characterization of psychological functioning as information processing). We argue, however, that human psychological functioning is in fact *doubly* artificial, since the environments to which it is an adaptation are themselves artificial and contingent, the products of design.

In short, then, DR as usually practiced within the Learning Sciences is the design of artificial settings in which to study natural processes, while a CHAT-inspired DR is the design of artificial settings in which to study processes of design (i.e., “courses of action aimed at changing existing situations into preferred ones”). Our proposal will be that CHAT-inspired DR is a science of the artificial in the double sense that we have just articulated. This paper will illustrate this proposal by describing a form of CHAT-inspired DR that involves creation of a out-of-school activity setting, the Fifth Dimension.

DR has been at the core of the Learning Sciences, in so far as LS involves the study of learning outside the laboratory in real world settings. DR has been defined as having “dual goals”: contributing to educational theory as well as educational practice. However, in the 20 years since it was first defined, DR has been criticized in various ways. It has been accused of paying insufficient attention to theory, and as often amounting merely to the testing of theory whose origins come from outside the classroom. Instead, it has been argued, DR offers the potential for “ontological innovation,” the positing and validation of new “categories of existence in the world” (diSessa & Cobb, 2004, p. 84). We agree with this proposal, and will illustrate such innovation in the Fifth Dimension.

At the same time, DR has been accused of paying insufficient attention to practice, in the sense that it is usually the researchers’ definition of the practical goals of the design intervention that are emphasized. Instead, it is argued, DR should adopt a more critical stance, and seek to “develop sociotechnical structures that facilitate individuals in critiquing and improving themselves and the societies in which they function” (Barab et al., 2007, p. 263). We also agree with this proposal, and will illustrate the role of critique in CHAT DR.

In addition, DR has been accused of lacking a clear and explicit logic of inquiry, an “argumentative grammar,” that is, a clear statement of “the logic that guides the use of a method and that supports reasoning about its data” (Kelly, 2004, p. 118). It is important to note, however, that Kelly assumes that DR is at its heart a form of research that seeks to identify what is “necessary” in a situation of learning, and to separate this from what is “contingent” (understood as “arbitrary”). Simon’s insight that cognitive science, and by extension educational research and in particular Learning Sciences, is a science of the artificial, that is to say of the contingent, appears to have been lost. Our own starting place, in contrast, is with the observation that what is “contingent” - in the sense of what is locally customary and valued - is equally important to practices of teaching and learning as what is necessary, and that what appears necessary often turns out to be contingent.

We believe that when DR is properly understood as the design of (artificial and contingent) environments in order to study (artificial and contingent) practices of learning, an adequate argumentative grammar can be provided. We shall outline such a grammar in the form of answers to the following questions: (1) What is the unit of analysis? (2) How is change conceptualized? (3) What kind of explanation is sought? and (4) What counts as evidence?

Our presentation will offer, justify, and exemplify the following answers to these questions:

- (1) The unit of analysis is the activity system and its associated cultural practices created by participants from (at least) two different institutions.
- (2) Change is conceptualized as having its source in contradiction. Change can include not only learning and development but also dissolution and decay. An activity system may transform in a productive way or it can die; people can forget what they have learned.
- (3) Explanation takes the form of the detailed articulation of constitutive processes. A sufficiently detailed documentation of process-oriented design research makes it possible to observe constitution and to reconstruct it as a real sequence of events.
- (4) Evidence is obtained by researchers who are themselves participants in the design process, tracing and documenting cultural practices over extended periods of time, at several levels of analysis, using a variety of methods (field notes, audio and video recordings).

The goal of the project to be described is to change, and where possible, reduce, constraints on the activities to be designed in order to obtain a deeper understanding of the learning potential of activities, in circumstances that differ markedly from the institutional constraints of standard classrooms. We have taken this route because Learning Sciences DR in the classroom typically takes for granted - and leaves unchanged in many respects - the institutional roles that are defined by the school: those of student and teacher. DR may, and often does, seek to transform these roles, but it does not, and arguably cannot, eliminate them. Yet these roles impose severe constraints on the character of learning and teaching. The people who inhabit such roles must cover curriculum, often defined by externally imposed “standards,” and they must implement forms of evaluation that lead to scores on tests, grades in courses, and ultimately ratings of their school. Within these constraints details can be changed - such as whether students work together and on what, whether the teacher is the primary source of information or not - but the fundamental logic of the institution must be accepted by researchers as much as by the participants with whom they conduct their studies.

CHAT-inspired design research outside the school classroom takes advantage of the fact that it can, in contrast, start without many of these institutional constraints if not from scratch. Our design research in San Diego takes place in the Learning Center of a government-subsidized housing project. In Bogotá it takes place in a small apartment rented from the parents of one of the founders of the non-profit organization Inti Tekoa, with which we are collaborating. In both cases, children and youth simply drop in from the street, or are dropped off by a parent or come with older family members. In San Diego, the adolescents and young adults come from the local university. In Bogota, the adolescents are enrolled in a “social service” requirement for their secondary school, but we have worked hard to confound their expectation that they would find themselves in something like a school classroom. In this basement apartment we can paint on the floor, decorate for Halloween to create a House of Horror, spray water, cut watermelon, invite in a passing dog, and simply mop the floor afterwards.

On the other hand, each of the participants at this site is involved in one or more institutions elsewhere: the university, the secondary school, their family. Each of us arrives with expectations, and with dispositions to act and interact that have been shaped by years, sometimes decades, of involvement in these institutions. Some of these expectations and dispositions transfer well into the site, while others do not. Documenting how the contradictions among these expectations are resolved by participants by virtue of their collaboration in, and in order to collaborate in, activities provides us with evidence we can use to reconstruct how our work in designing the site articulates with the ways participants are themselves artificial, products of design processes of education and work.

## **Formative Interventions and Transformative Agency: Principles, Practice, and Research**

Yrjö Engeström and Annalisa Sannino, CRADLE, University of Helsinki

Some 35 years ago Urie Bronfenbrenner wrote that “research on the ecology of human development should include experiments involving the innovative restructuring of prevailing ecological systems in ways that depart from existing institutional ideologies and structures by redefining goals, roles, and activities and providing interconnections between systems previously isolated from each other” (Bronfenbrenner, 1977, p. 528). This recommendation remains largely unheeded in educational research. This may be so in part because the transformative agency of the learners and teachers has seldom been taken as central challenge in design-based research.

Bronfenbrenner referred to Soviet cultural-historical activity theory as a key inspiration. The historical legacy of cultural-historical activity theory is one of theoretically and methodologically argued interventionism. This interventionist legacy has been picked up and systematically developed further in a few places in today’s world, including Helsinki, Paris, and San Diego. We will present the Helsinki variation, which we will call a methodology of formative interventions (Engeström, 2011).

This idea of formative interventions is being adopted in various educational research communities internationally (e.g., Anthony, Hunter & Thompson, in press; Bronkhorst, Meijer, Koster, Akkerman & Vermunt, 2013; Eri, 2013). Research done using formative interventions focuses on transformations and learning in object-oriented activities (Greeno & Engeström, in press), often outside schools, in workplaces and communities (e.g., Mukute & Lotz-Sisitka, 2012). The object of these activities is not self-evident; it is typically at risk or in crisis, ambiguous, fragmented, and contested. The object is rediscovered as a result of historical and empirical work of data collection and analysis with the help of conceptual models by the researcher-interventionists and the participants. The object is inherently contradictory from the beginning. Negotiations emerge as shared tools and concepts are built to depict and handle the contradictory object and the conflicting motives related to it. The emphasis is on the creation and implementation of “germ cells”, foundational models for new patterns of the activity, usually first constructed in relatively bounded units that then open up, expand and multiply.

The methodology of formative interventions is built on two epistemological principles, namely (1) the principle of double stimulation and (2) the principle of ascending from the abstract to the concrete (Sannino, 2011). The first one was formulated and implemented by Vygotsky and his colleagues (e.g., Vygotsky, 1997). The second one stems from the classic works of Hegel and Marx, was brought into activity theory by the philosopher Il’enkov (1982), and systematically implemented as foundation for a theory of learning and instruction by Davydov (1990).

The principle of double stimulation, in its full Vygotskian version, regards developmentally valuable learning as a process in which the subject faces a paralyzing conflict of motives (first stimulus) which is resolved by discovering an artifact which is filled with meaning and turned into a sign (second stimulus) that enables the subject to redefine the situation and to take volitional actions to break out of it. The principle of ascending from the abstract to the concrete depicts developmentally valuable learning as transforming a problematic situation to discover and model an initial “germ cell” abstraction that is then applied and implemented to construct a complex new concreteness. Both principles put the formation of volitional action and transformative agency in the center of learning. We define transformative agency as breaking away from the given frame of action and taking the initiative to transform it. The new concepts and practices generated by this type of expansive learning activity are future-oriented visions loaded with initiative and commitment from below. They cannot be predefined and safely constrained by researchers or authorities.

For about 20 years, the methodology of formative interventions has been implemented in practice by means of a toolkit called the Change Laboratory (Engeström & al., 1996; Virkkunen & Newnham, 2013). The Change Laboratory is used when an activity system or a cluster of activity systems faces an uncertain but necessary transformation riddled with conflicting motives and energized by a possibility of reaching a qualitatively new, emancipated mode of activity. In Change Laboratories the practitioners, including students, take over the leading role in designing their future. The taking over is a crucial feature of a formative intervention. This means also that the end result cannot be fully determined ahead of time and controlled through the process. The very point is to generate the unexpected - learning what is not yet there. This does not mean that the interventionists do not bring in their own ideas and aims. The dynamism of the intervention stems from the tension and interplay between the interventionists’ and the practitioners’ ideas and intentions.

We will describe and analyze three Change Laboratory interventions (one conducted in an academic library in Helsinki, another one conducted among greenhouse vegetable growers in western Finland, and the third one conducted in a school in Moscow, Russia) as implementations of the two epistemological principles.

The methodology of formative interventions generates several varieties of research. These include (a) studies of manifestations of contradictions (e.g., Engeström & Sannino, 2011); (b) studies of expansive learning

actions and learning cycles (e.g., Engeström, Rantavuori & Kerosuo, 2013); (c) studies of expressions of transformative agency (e.g., Engeström & Sannino, 2013; Haapasaari, Engeström & Kerosuo, in press); and (d) studies of concept formation (e.g., Engeström, Nummijoki & Sannino, 2012). We will conclude by discussing these varieties and the prospective next steps in the development of formative interventionist research.

## **Designing for Possible Futures: The Potential of Social Design Experiments**

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This paper is about designing for educational and social possibilities—designs that in their inception, social organization, and implementation squarely address issues of cultural diversity, social inequality, and consequential learning. We draw on a cultural historical activity theoretic framework to discuss the development of sustainable and resilient learning ecologies for non-dominant communities. Researchers working within this tradition employ a diverse range of theoretical perspectives, including cultural historical activity theory, to attend to the mediating role of social contexts and practices in human meaning-making processes and the role of researchers' efforts to improve the human condition of which learning is fundamental (Gutiérrez & Vossoughi, 2010). The goal of this work, then, is to make possible a sustainable and dignified life for all humans. This requires an interventionist stance that designs for new possibilities. Within this work, the approach to design focuses on re-mediating (Cole & Griffin, 1983) the effects of social inequity on vulnerable ecologies and communities who live in “tight circumstances,” with particular attention to making visible the ingenuity in human activity (McDermott & Raley, 2011).

### **Envisioning New Forms of Intervention and Design**

There are different kinds of interventions; however, few are theorized in ways that address a core human problem: our inability to resolve issues of cultural diversity and social inequality, to provide polycultural solutions, or to understand where one can allow for variability without turning it into a deficit (Cole, 1998; Gutiérrez, 2008). There is a need to formulate an alternative social science with a new social imagination, with some scale of social concept about how people can learn resonantly, as they live together productively and interculturally in resilient ecologies (Walker & Salt, 2006). There are extant models of this kind of formative intervention research in the field. The “change laboratory,” for example, involves the collaboration of practitioners and researchers around an important and consequential problem of practice within an existing activity system (Cole & Engeström, 2006; Engeström, 2011; Engeström & Sannino, 2010).

Within this tradition, we discuss a new form of design: social design experiments (SDE)—cultural historical formations concerned with social consequences, transformative potential, and new trajectories for historically vulnerable people, especially people from non-dominant communities (Gutiérrez, 2008; Gutiérrez & Vossoughi, 2010). Organized around expansive notions of learning and mediated praxis, social design experiments are oriented toward transformative ends through iterative processes of mutual relations of exchange; specifically, SDE's seek to (a) leverage the histories and repertoires of practice of members of non-dominant communities to envision new futures and trajectories; (b) introduce new tools and practices for envisioning new pedagogical and social arrangements; (c) underscore the role of diversity in ecological resilience and in re-mediating and sustaining viable and thriving ecologies; and (d) develop ecologically valid interventions and representations.

Following Erickson (2006, p. 225), SDE's require sustained first-hand observation, sharing in the action and cognition of practitioners and community members. Studying “side by side” with research partners jointly engaged in work to transform systems involves the researcher assuming the role of a collaborative partner and a reflective “observant participant” who helps make visible the practices, meanings, and contradictions that often become invisible to those closest to the action (Erickson, 1986, p. 157; Gutiérrez & Vossoughi, 2010).

### **Two Models of Social Design Experiments**

We elaborate two very different examples of social design experiments at very different scales to make the case for a design methodology distinguished by its grammar of hope, possibility, and resilience (Gutiérrez, 2011). To do so, we illustrate some key dimensions of this approach across cases. One illustrative case, an educational intervention, privileges intergenerational collaboration that foregrounds the agency of learners in ways that are distinct from the agency of designers and policy makers, for example, and emphasizes cross-institutional partnerships that promote new forms of engagement around learning; mediated by new technologies and divisions of labor, learning is reorganized in ways that create spaces to experiment pedagogically across institutional settings: the University and the community.

The second case involves a research team that has been studying a constellation of groups involved in the local food justice movement in three Western U.S. cities. The groups have chosen to focus their study on issues of food access among the most underserved communities in the state. These include people living in

poverty, vulnerable immigrant populations, and historically marginalized communities residing in neighborhoods with limited access to healthy and inexpensive foods. The problems facing these communities are entangled across multiple scales that include government (federal, state, and local), historical patterns of immigration, and shifts in global and local economies. Understanding how groups have chosen to intercede in the food system so that it can better serve vulnerable communities requires studying their efforts at rescaling across multiple levels of activity. We articulate the work of *equity-oriented scalemaking* in the local food justice movement drawing on examples from our multi-sited research study (Jurow, et al., under review). That is, given the fact that there are no ready-made answers to solving the problem of inequity in this system, these groups have developed unique strategies for transforming relations between communities, local food (its production, distribution, and consumption), and the geospatial organization of access to educational, environmental, health, and economic resources (Kurtz, 2013).

Though these two examples differ in their scale of intervention, they share important design principles that make the history of the ecology and its participants, available resources, diversity, resilience, and the possibility of new trajectories central to the conception of the design. Of significance, these interventions build for resilience and sustainability across longer timescales. Thus, while these interventions are aimed at local and institutional change, as social design experiments they are also aimed at broader social change through small and larger scale instantiations or realizations of a possible future. We argue that collectively these approaches become generative of a new imagination that conceives of resilience over cultural historical time, a resilience that encompasses ecological thinking about social and environmental systems, including educational systems. This is critical if we are ever to conduct research on learning and design for the social good in ways that have transformative and enduring consequences for people in vulnerable communities.

## **Negotiating and Accomplishing the Object of Design in Research-Practice Partnerships**

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In Cultural-Historical Activity Theory (CHAT), understanding the *object* of activity is what helps us make sense of why individuals, groups, or organizations do what they do (Kaptelinin, 2005). The object bounds analysis of activity systems and interactions between activity systems: it is the reference point from which researchers develop claims about the organization and effects of activity (Spinuzzi, 2011). The object is also often understood as a kind of “shared problem space,” and as such, a site of intervention, transformation, and learning (Akkerman & Bakker, 2011; Engeström, 2011; Engeström & Sannino, 2010).

Research-practice partnerships are emerging as new forms for organizing intervention research in the learning sciences (Coburn, Penuel, & Geil, 2013). In these partnerships, the object of design emerges through joint negotiation of researchers and educators in particular educational systems, such as school districts (Penuel, Coburn, & Gallagher, in press). At the same time, the problem spaces of design often have the character of “runaway objects,” that is, objects held in common across multiple activities that take place across multiple settings and with different configurations of actors (Engeström, 2008). Research-practice partnerships in education today take on such objects as “improving instruction at scale” (Cobb & Jackson, 2012) and “improving the success rate of community college students who place into developmental mathematics” (Dolle, Gomez, Russell, & Bryk, in press). As with other runaway objects, these are not in any single person, group, or organization’s control, including participants in partnerships.

The work of partnerships takes place at the boundaries of the cultural and institutional communities of researchers and practitioners. Researchers and practitioners’ cultural and institutional contexts are distinct, but also related. They are distinct, in that the objects, tools, and community practices of researchers differ widely from those of educators in schools and other settings (National Research Council, 2012). At the same time, the two worlds are related, because much of educational research aims to inform or directly intervene to improve educational practice. In addition, there are many people and organizations who move across these boundaries and broker connections between them (Penuel et al., in press). Research-practice partnerships often entail the construction of boundary zones where they negotiate the object(s) of their design work, as well as boundary practices, hybridized forms of practice that they design to help accomplish the partnership’s object(s).

## **Constructing a Boundary Zone to Negotiate the Object**

Work at the boundary of research and practice often requires constructing temporary spaces for negotiating the object of joint work and engaging in collaborative design. A key challenge to negotiating an initial object is to identify, name, and confront problems or challenges that are of mutual concern to participants in the partnership. Because researchers and practitioners often define their respective problem spaces differently (National Research Council, 2003), overcoming this challenge takes time and can benefit from explicit discussion and negotiation (Dolle et al., in press). At the same time, the process may be facilitated when the work practices of

both researchers and practitioners have been disrupted, such as through the introduction of new policies affecting both research and practice. These policies may help partners to identify a “shared problem space” (Akkerman & Bakker, 2011), an object that they agree is important and that requires the ongoing mutual engagement of researchers and practitioners to accomplish.

### **Accomplishing the Object in Research-Practice Partnerships**

The objects that give meaning to partnership activity require that partners influence activities outside the boundary zone. Sometimes, the object of a partnership requires mainly influences on mechanisms of coordination in systems. Examples include work focused on the coordination of professional development across role groups in school districts (Jackson & Cobb, in press) and work that aims to coordinate youth’s opportunities to pursue science-linked interests across school and out-of-school settings in a community (Penuel et al., 2012). More common, however, is work that aims to develop new *boundary practices* that can help partnerships accomplish objects focused on transforming educational systems. The aim of such work is transformation (Akkerman & Bakker, 2011), in which new, hybridized practices that bring together elements from research and practices are developed and, ideally, integrated into new routines and procedures throughout the system.

### **An Example: The Inquiry Hub**

The Inquiry Hub is a research-practice partnership among researchers, curriculum publishers, and a large, urban school district in the Western United States. The Inquiry Hub’s activities are funded through a grant from the National Science Foundation (NSF); its principal investigators include representatives from both research organizations and the district. The partnership’s activities are framed by the object of the funding agency, improving STEM education through researcher-initiated research and development projects. However, the specific object of the partnership is a focus of ongoing negotiation, and the resources allocated through the grant to accomplish the partnership’s object are shaped by those negotiations.

The partnership’s boundary zone is a fluid space comprised of a stable set of institutions in which specific partners change over time. It includes educational researchers with different forms of expertise (e.g., mathematics, assessment, professional development), software engineers, curriculum developers, district leaders from different departments and with different kinds of authority for decision making, and teachers. It is constituted through regular meetings whose agendas differ, depending on the composition of the group. A leadership team meets via telephone on a weekly basis to negotiate the overall work of the partnership, and a Teacher Advisory Board (TAB) meets with that team regularly to engage in design work.

The negotiation of the shared problem space is an ongoing activity within the Inquiry Hub, in part because of the changing needs of the district and differences in perspectives among the partners. Initially at least, the object of the partnership was to support adaptation of varied forms of “student-centered” instructional materials in mathematics and science throughout the district. However, with adoption of new standards in mathematics (Common Core State Standards), the district saw a need to focus more attention on developing understanding of new standards and the kinds of tasks that embodied the new standards. Teachers on the TAB, for their part, suddenly had a need for new instructional materials related to standards that had not been part of the curriculum before. These needs created a shared problem space related to the new standards, but it also led to some conflict over strategies for accomplishing the object of supporting implementation of new standards.

That conflict is reflected in the different perspectives on the design work of the TAB, which has focused on developing a new set of boundary practices related to instructional tasks in mathematics. The practice focuses on selecting, rating, and distributing instructional tasks in Algebra. For the researchers, the practice is a site for sociotechnical design: creating scalable social processes for supporting the task rating process and a technical (Web-based) infrastructure for distributing tasks and task ratings. For district leaders, the task rating process is a tool for developing awareness of what constitutes cognitively demanding mathematical tasks that can meet new standards. For teachers, the process of rating and distributing tasks is principally a means to discover new materials they might use in the classroom.

The partnership is also challenged by difficulties in crystallization of the boundary practices within ongoing routines and practices of the district. As with other boundary practices, the practices of the partnership are “subject to political processes, having a mediating role for contrasting goals, possibly reinforcing power structures and occupational hierarchies” (Akkerman & Bakker, 2011, p. 150). Making other teachers aware of tasks available to them in the technology infrastructure and providing professional development in the task rating process requires that the district partners gain and secure access to times when the district provides professional development to teachers. It also requires TAB members to gain access to agendas of teacher team meetings in their own schools. These are both settings where other district leaders not part of the partnership, as well as leaders of other initiatives and partnerships, compete for access to teachers. The partnership has yet to make its particular boundary practices “obligatory passage points” all teachers in the district must attend to and join as participants (c.f., Christiansen & Varnes, 2007).

In the Inquiry Hub, attending to boundaries foregrounds the need to confront multiple perspectives on the object of design in partnerships. All design research produces new practices that require ongoing work to sustain; however, a focus on these practices as boundary practices reveals potential sources of difference and conflict within the partnership. In addition, a focus on the challenges of crystallization of boundary practices reveals the ways that partnerships compete for scarce time and resources with other initiatives in educational systems, some of which may share the same object but pursue different strategies for accomplishing that object.

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# Mapping the Distribution of Children's Digital Media Practices: Methodological Innovations and Challenges

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**Abstract:** The papers gathered for this symposium draw from an interdisciplinary group, who are using a range of existing methods and developing new methods, to forge a new constellation of work in the learning sciences and allied disciplines with stakes in children's media practice. Across the group, we find different proportional commitments to the work of either filling in the map of how and where digital media practices travel, or documenting the lived practices of the inhabited territories such as homes, community centers, and neighborhood streets. Together we share a commitment that youth media practices need to be understood in terms of both senses of distribution. Bringing these sorts of approaches together is not without challenges, which will be a focus of our symposium presentations. Our synthetic work will be to explore what can be shared, where to locate tensions, and what new questions this new approach may yield.

## Symposium Overview

An historical reading of the learning sciences first two decades as a named enterprise suggests an important and productive shift in leading conceptions of cognition and knowledge, from cognition and knowledge as understood as something exclusively *inside* individuals to *distributed across people, tools, and physical places*. This sense of distribution is very important. But it has perhaps occluded an equally important sense of distribution, in the way that ecologists and geographers use the term. If, for analogy's sake, we treat a practice as a species, how do they move across time and space? How do practices migrate? Where do they settle? How do they change as they migrate? What routes do they take? As practices move and bump into each, do they compete? Do they hybridize? These are new questions for a next generation of learning scientists.

A timely arena for taking a run at these questions is youth media practices. In just a few decades, media practices have become far more diverse and far more mobile than ever. Based on data from national surveys, young people spend much more time with media technologies than they do with schoolwork of any sort. Young people between 8 and 18 spend as much as 50% of their waking hours engaged with media (Rideout, Foehr & Roberts, 2010); they spend no more than 19% of their time during these years engaged in subject matter work in school (Stevens, Bransford & Stevens, 2005). Media practices and media 'content' are therefore arguably a far more important source of young people's "cultural curriculum" (Wineburg et al., 2007) than schools, not more important in the sense of preferable but in the sense of pervasive. Yet we know so little about youth media practice and its role in the organization of youth learning, sociality, and identity formation, either in or out of school. This is perhaps ironic for learning scientists, who have such deep commitments theoretically and as designers to new media technologies to support learning.

Moving forward we need to be able to combine both senses of distribution in the study of youth media practice and, by analogy, the study of cognitive and learning phenomena more broadly. We need to be able to capture and describe the moment-to-moment details of youth media practice but we also need to be able to step back and see how media practices move and settle among peoples, places, and times. We need maps of media rich places and media deserts. Combining these two senses of distribution is potentially a 'new look' in the learning sciences because it offers the synoptic power of the map, without falling prey to mistaking the map for the activities in the inhabited territories. It may offer the possibility that 'cognitive ecologists' (Hutchins, 2010) might productively intermingle with, inform, and learn from ecologists who study the movement and settling of birds and fish.

The papers gathered for this symposium draw from an interdisciplinary group, who are using a range of existing methods and developing new methods, to forge a new constellation of work in the learning sciences and allied disciplines with stakes in children's media practice, namely psychology and communication. Across the group, we find different proportional commitments to the work of either filling in the map or documenting the lived practices of the inhabited territories, but together we share the commitment that youth media practices need to be understood in terms of both senses of distribution. Bringing these sorts of approaches together is not without challenges, which will be a focus of our symposium presentations. Our synthetic work will be to explore what can be shared, where to locate tensions, and what new questions this new approach may yield.

## **Constructing the Daily Media Round of Children: Methodological Innovations and Issues**

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Because many of the child-driven moments with media occur in informal, transitional periods of the day (Ito et al., 2009), very little is known about their content. Even less is known about how children's technology choices influence how they socially engage with others, both physically and virtually, and what they learn over the course of a day, week, or year from these interactions. In an era when video streams freely, "apps" marketplaces bulge with child-targeted content (Guernsey, Levine, Chiong, & Severns, 2012), and the shrinking sizes and wireless capabilities of media devices lend themselves to use in places beyond a parent's purview (Takeuchi, 2011), surveys of and even interviews with parents about their children's media use may be less reliable than they once were (Vandewater & Lee, 2009). New methods are needed to faithfully capture both child-elected and authority-sanctioned media use and its implications for engagement and learning in and outside of the home.

This research builds on the studies and goals of the LIFE Center and the Joan Ganz Cooney Center to understand how young people are learning and socially engaging with digital media within and between formal and informal educational settings. LIFE and Cooney Centers studies have documented the phenomena of joint media engagement (Stevens & Penuel, 2010; Takeuchi & Stevens, 2011) across a number of specific media contexts including television (Dugan, Stevens, & Mehus, 2010), e-books (Chiong, Ree, Takeuchi, & Erickson, 2012), video games (Stevens, Satwicz, & McCarthy, 2007), and creative technological expression (Barron, 2004). We also consider prominent national surveys that highlight the amount and kind of media experience young people have (e.g. from Common Sense Media, and the Kaiser Family Foundation). However, these studies have paid little attention to the ways that the ubiquity of mobile and networked media has affected the configuration of learning arrangements; "learning together" can occur across and between physical locations.

Our presentation focuses on the methodological innovations and issues associated with constructing the *daily media rounds* of young people. We use the "daily round" (Erickson, 2004; Taylor & Hall, 2013) to follow young people's digital media activity across various locations and times over the course of the day. Mapping this distribution as part of a case study methodology shows technology "hot spots" where young people are typically engaged in texting, checking email, watching television, editing movies, or playing video games, for instance. Constructing the daily media rounds of young study participants is a way of taking seriously the *mobility* of mobile devices and the ways in which an individual's digital activity can be extended across several different locations and times with co-participants. Not surprisingly, this extensibility influences family arrangements, dramatically altering the composition of joint media engagement (JME) involving parents, siblings, and peers within and around the home (Takeuchi & Stevens, 2011). This study focused on children 7 to 13 years old from a diverse range of family backgrounds.

To understand this dynamic and complex phenomenon of young people's daily media rounds, we have developed a study design that incorporates multiple methods of data capture. In the first stage of data collection, we interviewed the focal child and her parent about available technology in the home, parental regulations around media, and daily media routines in and around the home. In the second stage of research, we made detailed video recordings of naturally occurring activity during the hours after school, targeting times when focal participants are using media and technology (e.g., on the ride home from school, doing homework at the dining room table). Collecting video recordings also involved asking study participants to wear cameras so that we could see media content, especially if the child was "on the move." In the third stage of research, we conducted experience sampling over the phone for one week with focal children to better understand daily patterns and routines around technology. These conversations were audio recorded. The fourth stage of research was a "data sharing session" where focal children and the researcher mapped technology "hot spots" using a virtual geographic information program. This stage helped us understand how children's digital practices, sometimes with the same device (e.g., Mom's smartphone), extended across physical spaces, and if particular locations tended to elicit digital activity (e.g., sitting on the train to commute home). We then repeated stages

two through four and concluded the study with final parent-child interviews. Depending on scheduling with families and additional observations, the entire study lasted anywhere from six to ten weeks.

This study design has been replicated with children and their families in the Chicago and New York areas. Our only exclusion criteria were that focal children were between 7 and 13 years old and that they used media and/or technology during non-school times. We have collected data with families living in urban areas, suburban neighborhoods, single-parent homes, a home with five children, single-child homes, devoutly religious families, Black, White, Hispanic, and mixed-race families. As such, methodological challenges have been situated within participating families and the arrangements of those households. For instance, we studied a family with five children and only one smartphone in the home. Often, moments of joint media engagement involved the five of them crowding around the tiny screen of their mother's smartphone, sometimes to watch the YouTube video, "What Does the Fox Say?" In such instances, video recordings could only capture tops of heads and the audio barely emanating from the tiny phone speaker. This kind of record does not scratch the surface of the richness happening around the screen; the older children were mouthing the lyrics of the song, and the baby was bouncing up and down in rhythm on her sister's lap. The physical arrangement around the screen was constantly changing, although the child holding the device remained stationary. Furthermore, scheduling daily phone calls with two children to conduct experience sampling when there is only one phone between all of the family members is a major constraint for data collection. And finally, during observations, instances of JME are so frequent, so emergent, and so natural in the daily routines of families, that children rarely consider these as noteworthy or reportable to researchers during experience sampling and interviews.

At this point, findings and analysis are preliminary. However, our research team has been identifying and analyzing moments of JME from the video record. Preliminary findings suggest that the "mobility" of individual devices means that JME arrangements are much more fluid (as opposed to those taking place around a television). In some instances, the child with the device will initiate JME in one location, after which a participating or "following" child will take control of the device and move to another location. Perhaps surprisingly, sharing devices between family members has been less of an issue in this study for parents than the frequency of "distraction" from non-digital activities (e.g., piano lessons, eating, getting ready to go somewhere). Because digital media can be anywhere and everywhere now that mobile devices are prevalent, instances of JME often emerge during family routines that used to be "unplugged."

## **Conceptual and Methodological Issues in the Study of Young Children's Digital Gaming and Learning**

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This paper addresses conceptual and methodological issues involved in investigating the role of video gaming in young children's learning in the home. We use the term video gaming as an all-encompassed term that refers to games played on computers, game consoles, handheld gaming devices and mobile technologies of all sorts. Our discussion draws on our study of the gaming practices of primarily Mexican-American families with children between 4 to 6 years old. This is a particularly important age for children as learners and as gamers. This is the age when they enter kindergarten or the first grade of elementary school, and at this age there also is a significant increase in the time children spend on gaming (Rideout, 2013).

One conceptual challenge in research on video gaming is how to define and understand game play itself. While gaming might be understood quite narrowly as the interaction between a player (or players) and the "game-in-the-box," here we adopt a view of video game play in the home as a cultural practice, or more accurately, a set of practices that as Stevens, Satwicz, and McCarthy (2008) suggest are "quite tangled up with other cultural practices, which include relations with siblings and parents, patterns of learning at home and school, as well as imagined futures for oneself" (p. 43). This perspective suggests a need to understand the purposes that game play serves within the broader family setting, the meanings that game play has for family members, and how gaming might be viewed as an avenue for children's participation in family routines in ways that are desired – or not desired – within the home and family culture.

A second challenge is how to define and document learning. Through this work, we sought to understand how young children's participation in gaming-as-social practice reflected a broader enculturation into the shared beliefs, practices, values, and identities of their families and the larger social groups of which they were a part (Saxe, 1999; Tudge, Brown, & Freitas, 2011; Valsiner, 1986; Vygotsky, 1978). Video games themselves serve as agents of socialization as well as mediators of content acquisition and skill development. While we were interested in how children interacted with parents in ways that supported more obvious academic forms of learning (for example, the parent reading game-related texts with the child) we were also concerned with broader forms of learning, such as how family gaming practices contributed to a child's identity as a learner. Just as importantly, we did not wish to confine our investigation to the child's learning alone, and as

such we sought to understand how parents or older siblings might be participating simultaneously teachers and learners through out the gaming activities.

We explored these challenges in an ongoing study of the gaming experiences and practices of focal children ages 4 – 6 years old from primarily Mexican-American households. Our methodology included several phases of data collection through home visits over a period of approximately six months with each family. Structured interviews with parents and older siblings and inventories of digital technology in the home were used to construct a more general understanding of home media use and of gaming practices in particular. Family photo diaries, as a modified form of experience sampling, were used to document instances of game play over the course of the study. In addition to photo diaries, children's engagement with video gaming was documented through (a) loosely structured conversations with the child about games they play and household rules about games, (b) observations and "constructive interactions" (Benedikte, Jensen, & Skov, 2005) between the child and researchers during individual game play, and (c) observations of family game play sessions involving the child and other family members in the home. We also introduced the families to a small set of educational games and documented how these games were played and incorporated (or not) into the family game play routines.

In our discussion, we will first characterize the considerable diversity of family gaming practices as well as the ubiquity of gaming in most families' daily lives. In some cases it was literally impossible to separate gaming from other family routines. The rise of games on mobile devices has led to the incorporation of gaming into almost all places and spaces of family life, whether it be a 3ds game that keeps a child occupied during car trips or a tablet game that is passed around the kitchen table after dinner. However, this is just one example of the ubiquity of gaming as the ways that young children engage with gaming varies widely, range from less-structured, imaginative play with more open-ended games, in which the child is the primary driver of his or her actions and learning, to what might be described as legitimate peripheral participation in game play directed and scaffolded by others. The popularity of movement games for children of this age (using consoles like the Kinect and Wii) added an additional challenge to our investigation; the nature of a "constructive interaction" between a researcher and a child, breathless and hopping around the living room, needed to be rethought.

Results of this work include analyses of the learning opportunities afforded by these varied gaming practices. Initial findings suggest that young children's desire to participate in the gaming practices of parents and older siblings served as a particularly important driver for learning. Indeed, an important factor in children's learning through gaming is the extent to which older family members provide opportunities for them to observe and participate, albeit in limited ways, in games that are otherwise "over their heads." This is not a novel phenomenon; children's participation in everyday routines of the home as a form of learning has been well-documented by researchers such as Rogoff and her colleagues (2007). However, what is novel are observations of how adults and children negotiate what kind of participation is appropriate, and in doing so, create new gaming practices that in turn challenge both children and adults' ways of thinking and doing. Fathers proved to be particularly important in shaping young children's opportunities for gaming and learning. For example, in one family, the adults and older siblings regularly played multiplayer Halo (a popular shooter game involving slaughtering alien creatures) with extended family members who lived in different states. The father described how he had played Halo with his infant daughter dozing in his lap. In one of our observations, the daughter, now five, participated in family Halo game play by holding a controller and randomly firing away at aliens, giggling happily and cuddling with her mother, while also ignoring her mother's advice about how to play. This type of family gaming practice challenges dominant conceptions of what kinds of games and game play are appropriate for young children, as well as their roles as learners, by reframing the meaning of this game play in the context of family routines and history.

This paper contributes to our understanding of both the conceptual and methodological challenges of investigating video gaming practices and the learning of young children around games in the context of family life. The preliminary analysis of findings suggests that family video gaming practices can support the development of children's identities as gamers and learners through a learning process that extends across time and is distributed among family members, different gaming devices, and games.

## Mapping Neighborhood Learning Resources for Families

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This presentation focuses on results from a study that investigates publicly available community learning resources in order to inform the design of these resources to maximize benefit to underserved populations. Increasingly, learning opportunities are recognized as not contained within schools, but instead distributed across physical settings, virtual/online spaces, and across time. Schools, libraries, museums, and faith-based

centers all represent unique physical sites for learning. The digital world offers games, media, online communities, and informational sites. Research that follows learners across the settings and spaces they spend time in reveals the uniqueness of their learning ecologies as they pursue their particular interests and hobbies (Barron, 2006). Social networks are a core dimension of any learner's learning ecology and the expertise, interests, and depth of relationships among people shape the opportunities that arise. This social and relational variability can lead to substantial differences in how shared resources come to be utilized for learning. Our work is designed to contribute ideas for increasing the probability that families will access resources that can enrich their learning ecologies.

Research focused on institutions where learners spend time can offer important design-relevant and theoretical insights. For example, a recent study documented that for low-income families in particular, libraries are perceived as critical for providing access to the Internet, to reading material for their children, and to work related resources (Miller, Zickuhr, Rainie, & Purcell, 2013). When asked about new kinds of digital services that libraries might provide, Latino, African American, and poor parents were the most likely to report that they would find them useful (Zickuhr, Rainie, & Purcell, 2013). These ideas included providing access to devices that could be experimented with, access to library resources through mobile devices, access to media through kiosks located in the community, classes on how to use e-readers, and recommendations based on past library loans. At the same time, observational research has shown that parents' prior comfort level with technologies can influence the degree to which they jointly engage with their children around these public technological assets (Neuman & Celano, 2012). For example, research on library spaces is beginning to show the ways that learner's expertise and social partnering interacts with the physical, material, and symbolic resources to shape opportunities for learning (Neuman & Celano, 2012). We also know that even if a space is local, free, and open, barriers to access may exist that cause the resources to be underutilized. These barriers include lack of awareness of their availability, scheduling, and recent immigration (Castrechini & Ardoin, 2011). A better understanding of these dynamics is needed if we want to make the most of our public assets and support efforts to reimagine how libraries and other spaces might provide enjoyable and generative learning activities that can help all parents utilize digital media for family learning.

Our presentation will focus on findings related to two questions: 1) What types of community-based public resources for learning with and about technologies exist within three urban neighborhoods?; 2) How are community-based settings organized to support learning with and about technologies? Data collection sites include libraries, community centers, faith-based programs, Internet cafes, and schools that offer free computing-oriented learning resources for children and their families. We map these assets via visualizations with an in-depth look at libraries in particular. Dimensions catalogued include access to material computing resources (computers, printers, mobile devices, cameras), access to digital resources (Internet, software, games, and ebooks), access to social resources (mentors and librarians with expertise in computing), access to physical resources (space, tables, chairs), access to activities (organized programs like children's gaming or Internet scavenger hunt events).

Our methodology makes use of information visualization, a growing interdisciplinary area of research. We map public learning sites within a 1-2 mile radius of eight focal families homes that are part of Levinson's dissertation study. Our mapping displays locations and is based on a combination of Internet research, walking the neighborhoods, and informal interviews. Emphasis is given to a small number of focal sites. Interviews with representatives of each focal site provide data on material, digital, physical, social, and activity-based resources, and visualizations layered onto maps display summaries of these metrics. In a final phase, a smaller number of sites will be selected for observation. Twenty hours of observation across five sites document how resources are used. Time sampling and visual "sweep methods" (Given & Leckie, 2004) help us track activity in family oriented children's spaces. Our analysis focuses on describing activities, organized informal teaching & sharing practices, material resources, emergent interactional practices. We draw upon established surveys such as the National Center for Educational Statistics library and media instruments (e.g., <http://nces.ed.gov/surveys/libraries/school.asp>) in order to locate cases within national samples. Our goal is to begin to develop tools that can yield metrics and visualizations of the availability of free/low cost learning resources in a given community. These research tools include visualization ideas and inventories that might contribute to indices of the diversity and robustness of resources within particular neighborhoods. These in turn might serve as useful design/policy resources as well as open up new possibilities for research that tries to study connections between the density and quality of neighborhood learning opportunities and family and child learning.

## **Children's Media Engagement: Using Surveys to Complement and Inform Qualitative Research**

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This paper focuses on ways in which surveys complement and inform qualitative studies examining children's media engagement. It provides a detailed explanation of the opportunities for survey research to inform and bolster qualitative research while providing an overview of the limitations. Finally, this paper discusses the need for mixed method approaches of capturing children's engagement with media and the future role of survey research in this area.

Media are now ubiquitous in American children's lives (Common Sense Media, 2013). With media technologies expanding and children's use of media increasing, researchers, educators, and scientists are eager to understand the complex nature and potential effects of children's media use. Using a range of methodologies, researchers are beginning to understand the ways in which children use and interact with media in the home and school environments, the complex ways in which children learn from media technologies, and the ways in which families engage and use media together. Throughout this research, survey instruments help to provide the backdrop and context in which media use is occurring more broadly. The information provided by large-scale surveys helps to inform the direction of both experimental and qualitative research.

Surveys can complement and inform qualitative research by providing initial overviews of the current state of media use. Organizations and research institutions that are engaged in this issue often release results from nationally representative surveys of children's media use (e.g., Common Sense Media, 2011; 2013; Rideout, Foehr, & Roberts, 2010; Wartella, Rideout, Lauricella, & Connell, 2013). These surveys have been useful and are widely cited among the community of scholars, policymakers, media producers, parents, and others. In addition, the academic community has used survey data to generate a substantial body of research on children and media.

Survey research continues to be important in understanding media in children's lives. In fact, much of what we understand about this issue has come from survey research. Studies continue to proliferate not in spite of the utility of surveys, but because of it. One of the major strengths of surveys is their potential for both breadth and depth. Surveys typically (though not always) draw from large samples—even nationally representative samples—and allow researchers to describe a media engagement at a scale that will simply require too much time, resources, and effort for qualitative study. Surveys do well in setting the stage for deeper inquiry by providing a "lay of the land" in terms of addressing questions of "how much," "what," "who," and "where" of children's media use. Surveys have been invaluable in describing national trends in the amount of time that children spend with media, demographic differences, changes over historical time (e.g., Common Sense Media, 2011; 2013; Rideout and Hamel, 2006; Rideout, Vandewater, & Wartella, 2003). Survey research has also highlighted children's changing media ecologies—the "what" and "where" of children's media use. Studies have documented families' access to and use of different media over time, and these data have served as the background against which to examine trends in media adoption, use, and engagement, and the ways in which they shape children's development. Importantly, surveys have also identified gaps that signal inequity in media access and use (e.g., Common Sense Media, 2013; Pew Hispanic Center, 2013), which has important implications for policymakers and educators in efforts to equalize children's opportunities to gain experience and cultivate important skills with technology.

Surveys do not only provide a broad demographic backdrop against which children's engagement with media is examined; they have been useful in describing complex phenomena such as the ways in which family dynamics may shape media use, or outcomes that arise from children's media use. Drawing from an ecological model (Bronfenbrenner, 1986), researchers have used large survey datasets to understand how family contexts and parental behavior are related to children's media use. They found, for instance, that the type of rules (time vs. content) that parents had about media differed by demographic factors such as income and education, and that parents' rules about television viewing predicted different patterns of use among young children (Vandewater, Park, Huang, & Wartella, 2005). Another study based on a national survey tested three competing hypotheses on the link between family conflict and children's consumption of violent content on television and video games; it found that family conflict was positively related to children's use of violent media content, lending support to the notion that children's media use could reflect the violence modeled in their family environment (Vandewater, Lee, & Shim, 2005).

Surveys can also offer rich data on the impact of children's media use, particularly as they pertain to cognitive or social outcomes. The body of evidence that surveys have provided has deepened scholars' understanding of the nature of these effects. Researchers have found moderately adverse effects of television viewing: Watching television at before age 3 was negatively related to measures of cognitive outcomes at ages 6-7 (Zimmerman & Christakis, 2005). Others, however, have demonstrated the importance of content in determining the link between media use and outcomes, and uncovered positive relations between viewing educational television programs such as *Sesame Street* to school readiness skills (Zill, 2001).

In addition to large-scale national surveys, smaller surveys can be used within smaller environments to ensure that the experimental and qualitative research is being conducted with a sample that is similar to the population at large. Surveys can be included as a component in the more qualitative research to provide a

quantitative context and comparison for other researcher. For example, a group of researchers from Stanford, Northwestern University, University of Arizona, and the Cooney Center are working together to understand the ways in which families engage with media together. A principle component across each smaller research project is a survey. This survey will provide an overview media use and attitudes of all of the participants across the multiple sites of the project. Researchers have used mixed method practices like this for decades with great success (e.g., Barnhurst & Wartella, 1991)

It is important to acknowledge the limitations of using surveys when investigating children's media use. These limitations largely relate to the essential features of surveys: scale and the need for "quantifiability". Researchers usually field surveys on a relatively large scale and do not have the luxury of time or intimate knowledge of respondents. Surveys can take on an impersonal quality and tend to be quite brief (usually no more than 30 minutes) to reduce respondent burden. This can limit the depth and richness of data that researchers can gather. Further, the goal of survey research is to describe and understand phenomena *on aggregate*. Thus, behaviors, attitudes, motivations, and emotions—be they simple or complex—must be captured using measurable, pre-defined, quantifiable constructs. Surveys are therefore not adept at investigating complicated, nuanced, and multi-layered *processes*, including moment-by-moment interactions (between a parent and child around a digital game, for example), motivations, emotional responses, and the meaning that users make of and with media. This can often feel unsatisfying, as if the full range of complexity and richness around media use is diluted.

In modern life, where media use is increasingly untethered to a specific time and place, mobile, multi-platform, multi-sensory, and scattered throughout the day (in ever-briefer moments), conventional survey methodology is especially challenged in its ability to capture children's media engagement. Children and teens may also have greater difficulty reporting on their own media use under these conditions; the issue is also compounded with the reliance on parental report on media engagement for younger children.

Taken together, surveys have provided both breadth and depth in helping researchers understand the antecedents, contexts, and consequences of children's engagement with media. As with any research, mixed methods are needed to fully comprehend these relationships in nuanced and satisfying ways. In the era of new, digital, and mobile media, however, the need for innovative methods of capturing the full range of children's media experiences remains a challenge for large-scale surveys. When coupled with other methods such as ethnographies and in-depth interviews, surveys offer a powerful tool to arrive at this understanding.

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# Becoming Reflective: Designing for Reflection on Physical Performances

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**Abstract:** Learners' physical performances can serve as focal objects for reflection and insight across a variety of contexts and content areas. This session brings together a set of projects that leverage the physical performances of learners, construct concrete and abstract representations of those performances, and investigate how learners reflect on and understand the relationships between their performances and target content—physics, health and fitness, data literacy and navigation, animal foraging, and climate change. The session will share findings and design principles from each of the studies around constructing technological scaffolds for physical performance reflections. The symposium highlights the various ways performance can be used to engage learners, and how different settings and learning goals affect the designs of performance representations.

## Introduction

The use of participants' physical performances as a focal object has several potential benefits. It leverages peoples' (and especially children's) innate interest in the state and performance of their own bodies; the "quantified self" movement (Lee, 2013) is only the latest reminder of this phenomenon. Experiencing or witnessing the performance leaves little doubt as to the authenticity of the data set, nor, in transparent designs, to the relationship between performance actions and their representation as data. There may be immediate benefit (physical, cognitive, identity) to the physical performances themselves (Abrahamson, et al., 2012). Common to all of the designs presented here is the provision of opportunity and support for reflection, including both reflection-in-action (during performances) and reflection-on-action (before or after performances) (Schön, 1983). Each project, however, offers distinctive strategies for fostering reflection, differing in the goals of reflection, the objects of reflection, the nature of the reflective activity, and the temporal and social contexts of reflection. Taken together, these define a multi-dimensional design space for supporting reflective activities surrounding learner performances.

In the following we briefly describe each project, including a description of the participants, their performances, and the technologies used for capturing those performances. The remainder of each project description is devoted to addressing the following questions:

- *Goal(s) of reflection.* What is the purpose of reflection? How are the outcomes of the reflective process be used by participants?
- *Object(s) of reflection.* Beyond the performance itself, what facets of the performance are captured, and how are these represented and made accessible to participants?
- *Nature of the reflective activity.* How do participants work with and use the representations of their performances?
- *Temporal contexts of reflection.* How do the projects manage the scheduling, frequency, and duration of reflective activities?
- *Social contexts of reflection.* In what social contexts does reflection take place? What role do facilitators play in fostering reflection?

Tom Moher will serve as chair for the symposium. During the symposium, each speaker will briefly (10 minutes) present their intervention and their designs for supporting reflection. Discussant Andee Rubin will comment on the presentations, with the remainder of the session devoted to an audience-plus-panel discussion focusing on elaborating the list of design considerations outlined in this symposium.

## Devices, Dashboards, Games, and Reflections: Quantitative Data and the Subjective Experience of Fitness Technologies

Cynthia Carter Ching and Sarah Schaefer, University of California, Davis

The Learning Sciences has long been interested in how engaging with various kinds of digital representations of information and experience can facilitate learning and transformative change (e.g., Linn, Clark, & Slotta, 2003; Quintana, et al, 2004; Songer, 2007; Pea & Maldonado, 2006; Scardemalia & Bereiter, 1994). Recently, with the widespread nature of handheld devices such as smartphones and other wearable or portable technologies, there is great potential for such representations to be inclusive of a broad swath of learners' experiences within and across multiple sociocultural contexts (White, Booker, Ching, & Martin, 2012). For the most part, however, these representation studies have been focused on acquiring knowledge and habits of mind of some academic domain (usually mathematics or science), or perhaps learning to see everyday life through a domain-specific lens. Immediate impact on learners' everyday behavior, however, is not the typical goal.

This study has as its explicit goal the development of a device-and-gaming model for the improvement of adolescent health, via awareness of physical activity patterns and increased physical exercise. United States childhood obesity rates have doubled for children from 7% to 18%, and tripled for adolescents from 5% to 18%, since 1980 (Ogden, et al, 2012). Demographic studies also find that these national rates are disproportionately higher in low-income and minority communities (Calzada & Anderson-Worts, 2009). Changing physical activity behavior in sedentary individuals is a critical piece of a comprehensive approach to health improvement; however, studies employing pedometers in particular as a motivator typically find short-term but not long-term effects (Gardener & Campagna, 2011; Schofield, Mummery, & Schofield, 2005). The overall inquiry that this paper comes from aims to develop multiple ways for youth to engage with commercially available pedometers and their data, including in a narrative-driven online game that converts pedometer data into action events, and then to examine (a) the meanings youth construct around the various representations they encounter, (b) their reflections on the ways these representations relate to the physical activity contexts of their everyday lives, (c) the effects of this combination of meanings and representations on physical activity behavior.

For the past year, we have been working with an after-school program at an urban middle-school in Northern California, putting Fitbit™ activity monitors on approximately 30 youth ages 12-14 and talking with them about their reactions to the devices and their own data. Of the youth in our project, approximately 85% are on free and reduced lunch at school, 95% are non-white, and 67% speak a language other than English at home. Our data corpus consists of continuous device syncs during the four months in 2013 that students wore the devices, focus group discussions and individual interviews with a subset of students, multiple questionnaires and inventories, and pre-post BMI measurements. One of our first questions was how youth would react to wearing the devices themselves and the representations of their physical activity that the devices generate. Figure 1 shows two types of Fitbits™, both with digital displays that rotate (via a button or tap-screen) through numerical and graphical symbol representations of steps walked, calories burned, miles traveled, and flights of stairs climbed.



Figure 0. Device Display.



Figure 2. Commercial website dashboard display.

When we talked with youth about their experiences wearing the devices and the information they were getting about their physical activity, their talk focused primarily on the immediacy of looking down to find out, right then and there, how many steps or calories they had logged for a strenuous activity. Youth also discussed a great deal about subjective constraints that the data were not accounting for (such as "not everybody can walk to school"), or inaccuracies that they felt were giving them less "credit" than they deserved (such as questions about how many stairs counts as a "flight," and what happened if they rode bikes instead of walked). In most cases, however, the discussions were about the affordances of the device for immediate feedback, not about aggregates or larger patterns.

One of the ways that we hoped youth would reflect on aggregates or larger patterns was in looking at their profiles on fitbit.com. The commercial website associated with the Fitbit™ device has many more affordances for engaging with multiple representations of data. Figure 2 shows a snapshot from the first author's profile from 10/31/13, wherein the daily activity graph shows how activity is distributed over hours of the day (including a four-mile run in the morning and taking kids trick-or-treating in the evening). Yet when we

engaged in project activities taking youth to their profiles and encouraging them to look at their online data, they seemed confused or uninterested in the representations. Many of them needed help to decipher the graphs, and they did not make easy connections between what they saw on the graphs and their everyday activities until we prompted them individually asking specific questions such as, “what did you do yesterday between 5-6 pm that got you these steps?” In general, however, youth were not motivated to spend much time on their profiles.



**Figure 3.** Game interface display.

A third way for youth in our project to interact with representations of their physical activity is through a game interface, which will hopefully prove more compelling than the online profile graphs. On this aspect we have been working with an indie game developer, Funomena, to create *TERRA*, a narrative-driven online game (Figure 3). In *TERRA*, players are space explorers who have landed and set up individual domed bases on a desolate and uninhabitable planet, with the goal of completely terraforming it within a limited number of weeks so more of their people can come live there. Players explore and terraform the planet using energy generated by real-world Fitbit™ steps they've taken, which are boosted by the metrics of their home base. As the game progresses, the landscape of the world they create becomes an aggregate representation of their synced activity over the variable timeframe of the game campaign, with each player's landscape reflecting not only strategic in-game decisions but also the extent of their daily fitness. Investigating the effect of this in-game representation on youth insights about their activity and behavior is the goal of the coming year of the project.

## Getting Lost and then Found in Physical Data

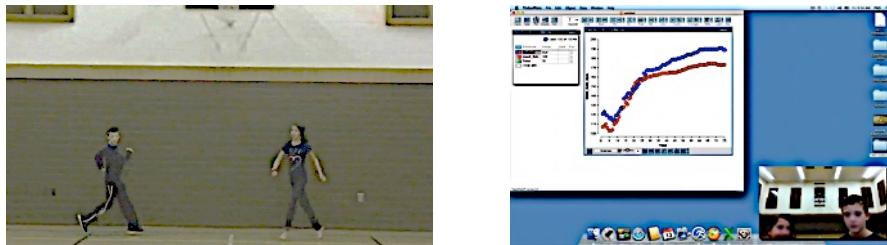
Victor R. Lee, Utah State University

This presentation draws upon two research and design activities that were both oriented toward providing fifth-grade students with opportunities to collect and reflect upon large amounts of data from their own physical activities while at school, using wearable physical activity data sensing technologies. In both efforts, students' reflections were anchored by canonical representations of those data, such as computer-generated timelines and histograms. Also, a design decision was made in both activities to ensure that while students would be directly involved in the process of generating data from their own physical activities, an instructor or facilitator working with the students knowingly withhold, at least initially, information about which specific activities from the data collection phase were associated with which portion of the computer-generated data representation. The rationale for this withholding of information was twofold. First, this added uncertainty was intended to encourage students to collaborate with their peers in reconciling the specific features of a given data representation with their recalled experiences of a physical activity. This is comparable to an approach demonstrated by Nemirovsky and colleagues in which episodic feelings of a bodily experience can be seen through conversation as becoming “fused” with representations of those experiences (Nemirovsky, 2011; Nemirovsky, Tierny, & Wright, 1998). Second, there was a methodological goal of eliciting students' ideas by requiring additional acts of explicit coordination for representation interpretation processes that are often both rapid and fleeting and may require prompting to uncover (Lee & Sherin, 2006).

In contrast to the aforementioned work of Nemirovsky and colleagues, a fairly long time delay between the bodily experiences and the representations to be inspected was also introduced. This was necessary because the wearable sensing technologies used were commercial, designed with specific capabilities and users in mind. Such devices are typically designed to support physical training and wellness goal attainment, as may be common for competitive athletes or active adults (Lee & Drake, 2013). As such, the data analysis software that was packaged with these devices tended to support summative reports of overall physical activity for periods of time longer than what is typically allowed during a portion of a school day. While those were real limitations, these commercial devices at the same time also provide a freedom of mobility and diverse set of features and capabilities that still made them in some ways more desirable than comparable devices designed primarily for children and schools (Lee & Thomas, 2011). So, to make the commercial devices work for the educational research and design purposes, small tools were developed to obtain fine-grained activity data (on the scale of individual seconds or minutes) that was stored on the devices but generally kept out of view of the intended users. These data were then provided in the TinkerPlots dynamic data visualization software (Konold & Miller, 2005), which was designed based on empirical research on student's intuitive reasoning of statistics and data

(Konold, 2007; Lehrer, Kim, & Schauble, 2007). This extraction and conversion process necessarily added in a time delay on the scale of several minutes.

Given that students had direct embodied experience with performing the physical activities that produced the data, that the exact match between data representation and experienced bodily activity was deliberately withheld, and that there was a necessary time delay between activity and data-supported reflection, the students were to some extent, ‘lost’ at the time of reflection. They knew and could draw on a few different resources and such had some familiarity with the terrain in which they had been placed, but determining what they were looking at and coming up with actionable interpretations constituted a metaphorical ‘wayfinding’.



**Figure 4.** Two students participating in the running activity (left) and then working together to identify who was associated with which set of data (right).

This presentation proposes this spatial metaphor of data interpretation as a wayfinding process in a space populated by recalled aspects of bodily experience coupled with representational features in a data display. The first activity in which this metaphor is used is one where pairs of students participated in a running activity involving each student simultaneously running around their school gymnasium but with each student running in a different way (forward, backward, or sideways depending on which lap they were completing). Their task was to determine which time-ordered line of recorded second-by-second heart rate data in TinkerPlots was theirs. The second activity to be analyzed with the ‘wayfinding’ metaphor was a portion of full class design experiment during which students calculated the distances of each of their strides using three different distance inference methods they had invented that each involved a combination of Fitbit activity trackers, high speed cameras, and rulers. In both the heart rate and stride length activities, students proceeded to test ideas about which set of data was associated with which activity based on pairings of specific recalled experiences with visual features on the data displays that were especially salient. Much as one might familiarize themselves to a new city by identifying some familiar landmarks and orienting themselves relative to those them, these students familiarized themselves with the data by way of identifying and orienting their recalled experiences relative to temporary ‘eventmarks.’ While this wayfinding process in data interpretation could be traced to the design decisions and constraints associated with the two activities, the suggestion made by this presentation and supported by other observations from the research project is that ‘eventmarking’ is actually a very sensible, and likely typical, way for people to make sense of inscribed data representations of what would otherwise be, in absence of a body sensor and performance capturing technology, ephemeral lived experiences.

## Action and Reflection in an Embodied Foraging Simulation

Tom Moher, Alessandro Gnoli, Anthony Perritano, Paulo Guerra, and Brenda Lopez-Silva, University of Illinois at Chicago; Mike Tissenbaum, James Slotta, Rebecca Cober, and Cresencia Fong, University of Toronto

Over the past year, we have developed a learning environment designed to support upper elementary learners' construction of understandings surrounding animal foraging behaviors. In *Hunger Games*, classroom learners enact foraging within the context of a sequence of increasing challenging simulated conditions of competition, resource depletion, sociality, and predation. The instructional unit is designed to develop understandings of the factors that foraging animals use to guide their decisions in selecting food patches, as well as the ways in which populations of animals distribute themselves among available resources. Students' (individual and aggregate) behaviors during enactment of the foraging simulations serve as objects of inquiry for reflective activities.

Early in the design of *Hunger Games* we made the decision to stage foraging as an embodied activity. We were inspired by a longstanding practitioner tradition of using embodied activities with physical materials (e.g., chickpeas, M&Ms) to introduce foraging concepts, and felt that an embodied approach had several potential advantages over a distributed screen-based approach (Goldstone & Ashpole, 2004). First, it more closely models the locomotive and visual demands on foraging animals. Second, it affords an unconstrained social context for activity, allowing students to share strategies spontaneously within the action space. Third, it allows for the emergence of deceptive and despotic behaviors (e.g., misinforming others about patch yields, physically blocking access to food patches) with parallels in the animal world. Finally, we felt that using an embodied simulation had strong motivational potential for upper elementary school learners.

In *Hunger Games*, each student in the classroom is provided with a small stuffed animal ("squirrel") that serves as his or her "avatar" during the activity (Figure 5). Students forage by moving their squirrels among a set of "food patches" of varying quality distributed around the classroom, gaining energy as a function of the elapsed time in the patch, patch quality, and competition within the patch (i.e., the presence of other squirrels) (Figure 6). Food items (e.g., acorns) are not explicitly represented, avoiding the demands on teachers for both



Figure 5. RFID tags are embedded in plush toys serving as "avatars" for student foragers.



Figure 6. Students foraging at food patches. Hidden RFID readers detect tags embedded in stuffed animals.

preparation (e.g., counting out large numbers of small items representing food) and data management (aggregating individual performances into representations of group performance). Students falling victim to predation (signaled on smaller displays adjacent to each food patch) are considered "injured," and given a short "time out" period in which their squirrel cannot gain calories even if located in a patch; this allows us to introduce predation without forcing children "out of the game" prematurely.

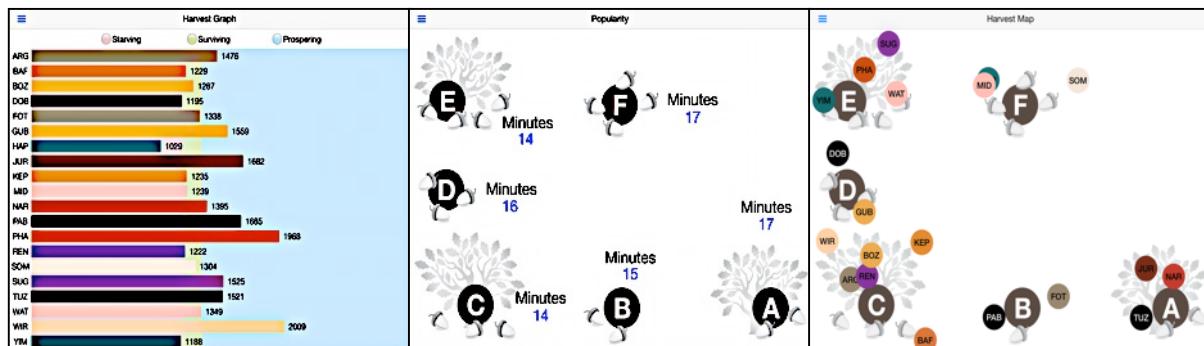


Figure 7. Public ambient displays used during foraging bouts. From left to right, the Harvest Graph (distribution of individual caloric gain), the Patch Popularity map (aggregate whole-class time spent in patches), and the Marauder's Map (the current location of all squirrels currently foraging).

*Hunger Games* is designed to support both reflection-in-action (during foraging) and reflection-on-action. During foraging bouts, participants have access to large animated public displays depicting the number of calories each squirrel has gained, the cumulative patch utilization, and the current locations of all of the squirrels (Figure 7). These representations are designed to support students' in-the-moment decision-making, but also to help learners develop understandings of how their actions impact the public representations (bar graphs, maps), setting the stage for post-activity reflection on their performances. Reflection on action is supported through the use of a community knowledge-building application (Figure 8). In that application, students are provided with representations of both individual and aggregate data reflecting their performance during foraging bouts. At the aggregate level, they have access to an interactive version of the Harvest Graph that allows them to sort the distribution of individual caloric gains according to various strategies surrounding patch quality, competition, frequency of moves, etc. At an individual level, students are provided with a "move tracker" that allows them to replay the step-by-step patch switches that they made within the context of the state of the system at the time of their decisions; this tool is used to support learner reflection on the effectiveness of their moves and to prepare for subsequent foraging bouts. Finally, the application provides a threaded discussion tool to support development of community knowledge around a series of structured discussions.

Following a pilot study in Fall 2013 (Gnoli, et al., 2014), we are currently enacting a four-week *Hunger Games* unit with three classrooms of grade 5 (10-11 years of age) students, focusing on learners' appropriation of

resources during foraging and knowledge construction. Our presentation will review our experiences in those classroom enactments.

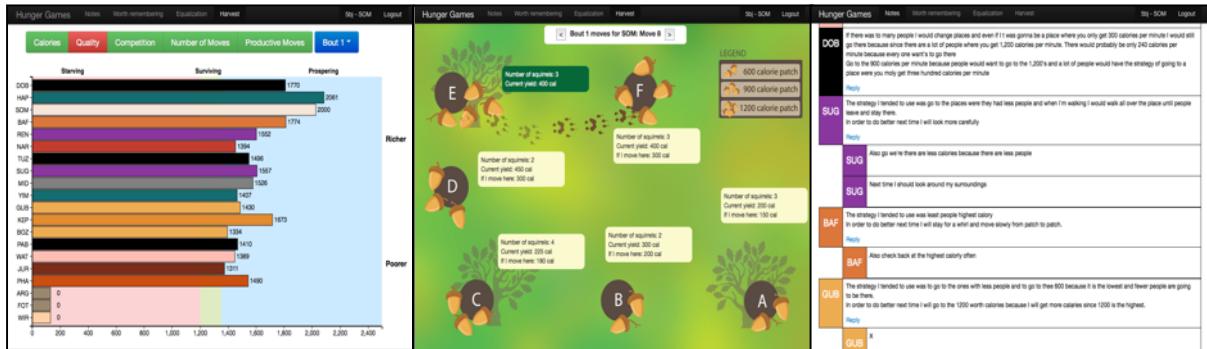


Figure 8. Tablet-based application to support individual reflection on action and community knowledge construction. From left to right, the sortable Harvest Graph, move tracker, and threaded discussion tool.

## Distributed Acts of Reflection: Embodied Acts to Focus and Filter a Jointly Produced Reflection

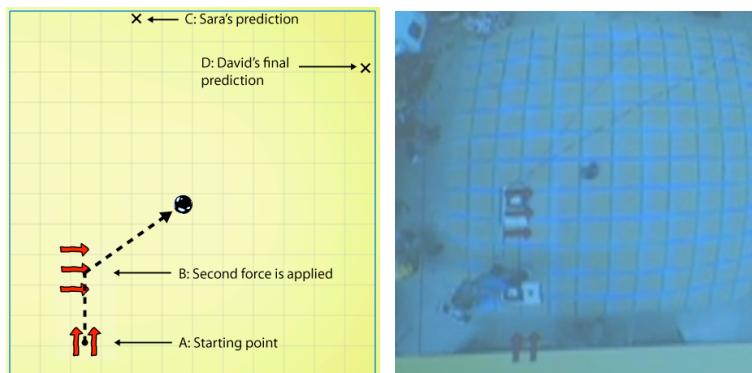
Noel Enyedy, University of California Los Angeles and Joshua Danish, Indiana University

Dewey (1933) defined reflection as “active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends” (p. 91. as cited in Spalding and Wilson, 2002). In this paper we explore the potential for supporting this kind of reflection in mixed-reality environments that combine embodied activity with augmented reality to support groups of early elementary students in reflecting upon and thus revising their developing ideas about the physics concepts of force and motion. Using data from the Learning Physics through Play (LPP) project (Enyedy et al., 2013), our analysis highlights the co-constructed nature of reflection in an embodied learning environment. Our analysis suggests that this form of mixed-reality environment provides unique opportunities for reflection.

The LPP environment is designed around the assumption that play, particularly embodied socio-dramatic play, can provide a unique opportunity for children to explore complex ideas. Specifically, we build on Vygotsky’s (1978) definition of play which notes that play always includes both an imaginary situation and a set of rules. In this framework, the imaginary situation supports students in reflecting about the rules of the situation even when those rules might otherwise be beyond students’ ability to engage with. LPP was designed to support this reflective play using two key components: 1) an augmented reality system that uses computer vision to record students’ physical actions and locations, and 2) software that translates this motion into a physics engine and generates a display and a response based on the sensing data. The LPP system uses commercially available, open source motion tracking and pattern recognition technologies (Kato, 2007) to create an inexpensive alternative to virtual reality within the physical classroom (a 12’ x 12’ carpet at the front of the classroom). Tracked motion is instantly imported into the new LPP computer microworld that allows students to model their understanding of force and motion and compare their predictions to simulated results. Thus their embodied play is enhanced with physics symbols in an effort to provide unique opportunities for reflection about how their play relates to the underlying science.

Our data come from the first LPP study (Enyedy, et al., 2013) in which 43 students (aged 6-8 years) engaged with the LPP learning environment to learn about force and motion. Our findings indicated that 91% of the students (39) demonstrated a significant pre- to post-test learning gain over the course of the 15 week curriculum. In the present analysis our goal is to further explore how the LPP Environment supported students’ efforts at reflecting upon the science content in a manner that ultimately led to these gains. To examine students’ process of reflection, we combine Piaget’s (1983) taxonomy of reflection with that of Davis (2003) to categorize the process through which students talk, gesture, and positioning reveal their reflection upon the underlying content. Piaget suggested three forms of reflection which attend to the physical properties of objects, one’s own actions in the world, and one’s own thinking (metacognition in more recent theories). This can be synthesized with Davis’ (2003) framework, which attends not only to the focus of reflection, but the content of reflection and distinguishes between actions (appropriate ways of behaving, a focus on goals); reflection on activities (the specific tasks assigned to students); reflection on the actual content being studied; and reflection on knowledge (monitoring or improving one’s understanding). The combination of frameworks will support us in examining how students move between these different foci, and how the combination of embodied play and symbolization in the LPP environment supports the process.

Our presentation will include several case studies that demonstrate how students move fluidly between reflecting upon the physical environment, the simulated environment, and their hypotheses about the rules that underlie both. Further, they use both the simulated world, and their embodied action as a method for supporting their ongoing reflection. For example, in one activity students were asked to model what they thought would happen if a ball that was already moving in a straight horizontal line received a force in the vertical direction (a kick) (Figure 9). A common misconception is that the ball will now move in the vertical direction rather than moving diagonally. While several students indicated their predictions, it is particularly illustrative to consider David who indicated his prediction by pretending to be the ball that has received the kick and walking across the space while placing a piece of string upon the ground to indicate his hypothesized pathway. Thus David uses his body and the string to reflect upon the rules he assumes will drive a ball in this situation, suggesting a blurring of the lines between a reflection on the physical world and one's actions. The teacher then runs the computer simulation, which does not trace the same path as David, a point that Sara is quick to point out. She reflects upon the contrast between the two and then indicates her own prediction by walking the same space with a different point in mind. Thus her reflection is made visible to the group through her embodied activity. David pauses while considering both before appearing to realize that the problem was not in his general model, but in his placement of the string that indicated his hypothesis—he had placed it at the edge of where the force was applied to the ball rather than the middle. Thus David's reflection appears to take into account his own thinking, the activity of the computer, the activity of his peers', and his own body in addition to the rules of what it means for a ball to be kicked! This combination ultimately allows him to produce this more accurate depiction, which his peers can then take up and reflect upon in turn.



**Figure 9.** The LPP window on the left depicting 2-dimensional motion. The dashed line depicts the path of the ball's motion once the simulation was begun. The ball was initially placed at point A, on top of a vertical force of 2. Once it began moving, the ball encountered the force of 3 at point B, which altered its trajectory. On the right is the mixed reality version that the students see based on the view of a camera mounted on the ceiling.

In this example, students' reflection in an environment such as LPP appears to move between taking multiple aspects of the environment as the object of reflection (the movement of a ball, the simulation of a ball by a computer, and one's peers' embodied predictions) and using these as tools to foster reflection. While at first blush confusing, it appears that it is exactly this synthesis of opportunities that leads students reflections and helps them to develop more normative accounts of the physics concepts. In this short segment we can see the new complexities and affordances that mixed reality provides for reflection. Empirical abstraction is augmented with new virtual objects (e.g., the quantifiable forces that float above the path of the ball) that fuse with the real world to afford new inferences and calculations. Pseudo-empirical abstraction is enhanced both by allowing new actions such as running the simulation and changing the parameters, but more importantly by allowing students to interact with each other and the traces that other people's previous actions have left on the system.

## Exhibiting Performances for Data Literacy and Climate Change Education

Leilah Lyons, Priscilla Jimenez, Brenda Lopez, and Brian Slattery, University of Illinois at Chicago

Informal learning institutions are increasingly incorporating full-body interactive experiences in their exhibits. Full-body interaction makes use of the motion and/or position of users' bodies as input to a digital experience, with the output typically presented on large displays mounted on a wall or floor as a projected image. Full-body interaction exhibits are known to be highly engaging for visitors who are directly involved in the interactions (especially younger visitors). Engagement alone does not necessarily translate into learning, however—visitors need opportunities for reflection (Allen, 2004). This is especially true for the many visitors who only

peripherally engage in the activity as spectators. They lack the firsthand experience of the interaction, and thus may struggle with understanding the performing visitor's actions (Reeves et al, 2005). In this presentation, we detail the design strategies we employed as we made visitor performances the cornerstone of an educational exhibit for a zoo. This setting allows us to leverage the power of using many visitors' performances to surface data literacy issues, but also introduces reflection challenges.

The Climate Literacy Zoo Education Network (CliZEN), a nationwide group of zoos and aquaria, developed a whole-body interaction exhibit, *A Mile in My Paws*, to address the worrisome trend that despite increasing evidence of climate change, the public has expressed less concern for its impacts. An APA report examining this issue recommends that in addition to exposure to data, learners need a personal or affective connection to the effects of climate change to begin building an understanding of the magnitude of the phenomenon (APA, 2010). One recommendation was that in addition to exposure to data, learners need a personal or affective connection to the effects of climate change to begin building an understanding of the phenomenon (APA, 2010). In our exhibit, a zoo visitor is put in control of a polar bear avatar that must traverse a simulated arctic environment in past, present, and future time periods in search of food. Users control the bear by "swimming" with motion-sensitive gloves (fashioned as plush polar bear paws) and walking in place on a pressure sensitive plate (Figure 10). As polar bears must work harder to swim given the shrinking of sea ice, so too must *Paws* users work harder by swimming more frequently as they play through the maps of 1975, 2010, and a projected 2045 maps (created using satellite data and model, Figure 10).



**Figure 10.** On the left, *Paws* in use in the Brookfield Zoo. Middle left, a player wears plush gloves containing motion sensors, and stands on a pressure-sensitive plate, to swim and walk, respectively, through three different decades of a simulated arctic environment (maps, middle right). The right image depicts the graphical representation of visitors' performances across the decade, with the most recent two visitors' data highlighted.

Kinesiology research has shown that people are remarkably reliable at judging the relative effort they experience with different physical exertions; we exploited this perception-of-effort as a means of affectively (and hopefully effectively) communicating the magnitude of climate change's impact on polar bears (Lyons et al., 2012). A controlled experiment helped us tune the glove weights (Lyons et al., 2013) so we could induce visitors to perceive later decades (more episodes of swimming) as more effortful for bears than earlier decades.

Users, especially young users, would notice but not realize the import of the increased effort unless it is pointed out to them. For this reason, the users' motions were logged by the system, and the calories they burned estimated and plotted on a graphical representation that zoo interpreters could use to emphasize the exhibit's educational message (Figure 10). This representation was displayed on either an iPad or a large monitor near the exhibit. The graphical representation of performance illustrates the magnitude of climate change impact on polar bears over time, and it helps demonstrate that variability in data does not invalidate trends. (Climate change skeptics often use variability in climate change data representations, like disagreements between tree ring and ice core temperature estimates, to dismiss the validity of warming). Visitors see their own data juxtaposed against the recorded performances of other, allowing interpreters to directly address the issue of variability-in-data. We leverage the large numbers of zoo visitors to make connections between the easily understood performance data variability and the variability in large climate change data sets. With this reflection-on-action (Schön, 1983), we expose visitors to the "core of statistics": "the task of understanding the world from incomplete or imperfect data," often missing from more traditional data literacy approaches (Rubin, 2005).

The post-performance reflection activity clearly offers potential educational benefits to both performers and spectators, but there was still the question of what educational benefit spectators would get during the performances (which last around 2 minutes). Moreover, spectators arrive and leave sporadically – there is no guarantee that they would stay for the post-performance debriefing. We were interested in making the performance more than just a shared anchor for discussion (Diamond et al., 1995) or a means of attracting visitors (Meisner et al., 2007) – because the performance itself is the subject of the exhibit, there was a need to support reflection-in-action (during performances) for spectators (Schön, 1983). The link between user actions and the effects these actions produce should be maximally "expressive, to enable the spectator to fully appreciate the performer's interaction" (Reeves et al., 2005). User actions in *Paws* were intentionally designed

to be as obvious and expressive to spectators as possible – to draw spectator attention to the swimming and walking motions performing visitors wear large plush gloves and slippers that look like polar bear paws (see Figure 10). Nonetheless, a special challenge comes with exhibiting effort – kinesiology research shows that spectators are notoriously bad at judging the effort (Lyons, 2012). Therefore, we needed to create a live representation of the performer’s exertion (Figure 11) that depicts both the player’s path across the arctic map and a running graph of how many calories they have burned.

A pilot study performed *in situ* at the zoo showed that interpreters could and did make use of the live performance data to engage spectators in reflection-in-action (Figure 11), as illustrated by this transcript:

[01:03:03.07] Visitor-Child: So where is he trying to go?  
[01:03:04.15] Interpreter: He’s trying to ... go to this red star which is a seal, so if the polar bear were to smell a seal, like up to like three feet of ice they can smell a seal underneath, they’d have to chase and follow it to where they could actually get it, so that’s what he’s simulating here  
[01:03:23.03] Interpreter: And as he goes we can kind of watch based on how far he’s going, how many calories he’s burning, and you’re gonna see this go way up, especially when he gets to these swimming areas, ‘cuz its a lot harder for the polar bear to swim than it is to walk.



**Figure 11.** Left, screen shot of live performance data, with a depiction of where on the map the performer is currently located and a graph of how many calories the player has burned over time (note the steeper slopes for periods where the player was swimming). Right, photograph of an interpreter (in green shirt, far left) using an iPad to engage spectators in reflection-in-action while another visitor performs.

During this exchange the interpreter gestured to the higher-slope regions of the graph, shown on the iPad device, corresponding to times when the performer had been swimming. We found that gesture was critical to the interpreters’ ability to engage spectators in reflection-in-action. Other trials, where the live graph was shown primarily on a large shared display, drew the attention of more spectators, but interpreters seldom highlighted any components of the data representations. By contrast, interpreters using the iPad used gestures to explicitly connect regions of the evolving graph to the live performance, and to the map. Ongoing work extends the “reach” of mediation to more spectators by supporting finger-based annotation and mirroring of the annotated iPad screen on large displays. A separate paper in this volume contains details on the iPads’ mediative roles.

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## Acknowledgments

The projects described here were supported by the following grants: NSF IIS-1217317 (Ching), NSF DRL-1054280 (Lee), NSF DRL-0733218 (Enyedy), NSF CCEP-I-1043284 (Lyons), and NSF IIS-1065275 and IIS-1124495 (Moher).

# **Enrollment of Higher Education Students in Professional Knowledge and Practices**

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**Abstract:** In this symposium, we discuss students becoming “enrolled” and appropriate the knowledge and practices of their prospective profession. This discussion and the related research are anchored in the acknowledgement that education programs should provide opportunities for learning and development of competencies required for knowledge-based work. We present empirical studies that examine learning in higher education courses in three different countries. These studies focus on student engagement, participation, and experiences in learning activities emphasizing knowledge practices that resemble professional work, and analyze how enrollment takes place and is facilitated by curriculum design and instruction. The findings show the nature and complexity of the knowledge practices embedded in the curriculum and how students become involved in these activities. The symposium delineates challenges for designing learning scenarios that support such enrollment. Ultimately, the symposium contributes to the ongoing discussion on how enrollment and curriculum design can stimulate and support knowledge-driven learning.

## **Introduction**

This symposium addresses the processes through which higher education students become enrolled in learning activities that resemble knowledge structures and practices that are characteristic of their prospective professions. Furthermore, it examines the way the education programs assist and support students in this process.

In recent years, the expansion and increasing complexity of each domain’s body of knowledge, and the use of state-of-the-art technologies that bridge geographically dispersed knowledge and resources have also profoundly influenced higher education. It is already widely acknowledged that profession-oriented higher education programs should provide opportunities for learning that match the professional knowledge practices and the competencies required to deal with knowledge-based work in general (Nerland, 2012). Workplace settings expect future employees to be proactive and capable to generate knowledge and collaborate with others, to use advanced tools, and to adopt epistemic modes of practice (Goodyear & Zenios, 2005). Accordingly, higher education is challenged to design dynamic and open learning environments with an emphasis on knowledge-driven activities (Healey & Jenkins, 2009). While there is agreement that such activities are beneficial, they remain complex and challenging for students. This highlights the necessity for facilitating the way students conceive knowledge-driven activities and their enrollment in the epistemic practices specific to each profession.

The main focus of this symposium is two-fold. *First*, it aims to unveil what characterizes *students becoming enrolled* in the knowledge culture and practices of their prospective profession, through the corresponding higher education programs. *Second*, it attempts to provide insights into how instruction and curriculum design in higher education supports such enrollment in education programs in three countries. Ultimately, the symposium aims at contributing to the ongoing discussion on how various knowledge practices characteristic to professional domains can be stimulated and facilitated.

## **Empirical and Theoretical Background**

Research on knowledge practices has examined how professionals devise and develop epistemic strategies for addressing open-ended problems, arguing that they need to conceive new knowledge, capitalize on collective expertise, and demonstrate inquiring skills and proactive behavior (Kerosuo & Engeström, 2003). This epistemification process (Knorr Cetina, 1999) that characterizes the dynamic changes in knowledge stems from modes of practice associated with those of science communities, in which knowledge production is one of the

core values and skills. Simultaneously, research on other professional practices, such as new product development or cross-functional units (e.g., Hyysalo, 2005), has shown that work is similarly artifact and technology-mediated. From a sociocultural perspective, human actions, including learning and interaction with others and their environment, are mediated by various means and tools (Wertsch, 1991). Knowledge objects are mediational means that can accumulate collective knowledge and experience and can represent resources for learning and activity. Objects are important because they represent and embody past learning and knowledge and, due to their functional complexity, are addressed to externalize existing understanding, but also to negotiate, design or test new ideas and solutions (Miettinen & Virkkunen, 2005).

Few studies have focused on the challenges students encounter when entering professions and the corresponding knowledge practices. Research examining practices of inquiry in higher education by Muukkonen and Lakkala (2009), and Stankovic (2009), and Damşa, Andriessen, Kirschner, Erkens and Sins (2010) pursued research that conceived learning as an activity that involves addressing complex knowledge-based problems, which requires collaborative inquiry and knowledge construction to reach appropriate solutions. Such complex processes involve a focus on shared understanding, joint actions at the epistemic level, and a good balance between work with knowledge and the management of the process. In addition, the research-based learning model brings aspects of the scientific knowledge culture and practice into educational settings, in an effort to organize learning that supports students in developing “epistemic fluency” (Goodyear & Zenios, 2007). Studies with this focus have provided some insights into how research-like activities have the potential to transform (undergraduate) students from course-takers to producers of knowledge (Shaw, Holbrooke, & Burke, 2011), or on the acceptance within disciplines that students can contribute to research and knowledge production (Brint, Cantwell, & Sazena, 2012). Lambert’s (2009) study showed how this type of learning has the potential to reconfigure students as intellectual producers through their active engagement and participation in the research cultures of their departments and disciplines.

## **Relevance and Contribution to the Conference**

In this symposium, we build on the aforementioned insights to better understand the knowledge culture and practices relevant to learning in higher education. Two aspects are of importance here: *how students’ engagement* in knowledge practices emerges and *what* is used and constructed, in terms of *knowledge and knowledge objects*. We use the notion of *enrollment* (Nespor, 1994), as an overarching concept depicting how knowledge structures and practices are mobilized, but go beyond the original conceptualization, by assigning students an active, participative, and sense-making position in this process.

The contributions in this symposium report on research that examines learning activities of undergraduate students in three different countries, highlighting the epistemic dimensions of the process. Common denominators for the three studies are the higher education settings, methodologies that attempt in-depth exploration of rich sets of data, and shared notion that students learn knowledge practices through active engagement and participation.

The *first study* examined how students from two Norwegian undergraduate programs, teacher education and computer engineering, respectively, become enrolled in and adopt the knowledge practices of their future profession through collaborative projects. The analyses of discursive interaction and of the use and construction of knowledge objects by student groups show that students’ knowledge practices reflect valued practices in their prospective profession, respectively, the sharing of personal knowledge in teaching and distributed problem solving, mediated by procedural standards in computer engineering. The *second study* explored how three Finnish undergraduate courses, i.e., development of business ideas and multimedia products, advanced themes in project management within the financial domain, and customer projects in the field of biosciences, were set up to engage student teams in the processes that simulate workplace practices in knowledge intensive organizations. It specifically investigated the participating students’ expectations of and learning experiences, and the assessment of collaborative outcomes and processes. The findings suggest that the students were eager to explore work-life and the knowledge of expert practices for customer projects by engaging in initiating and sustaining multidisciplinary collaboration, and by advancing the shared objects. The *third study* explored functional epistemic games for knowledgeable action and learning in professional education, with a focus on the nature of epistemic games embedded in tasks that aim to prepare students for externships in workplace settings. The participants were enrolled in professional practice courses in pharmacy, nursing, social work, school counseling, and education at an Australian university. The analyses focused on collected artifacts and interviews and depicted the characteristic patterns of situated inquiry that students were expected to learn. The findings suggest that learning for knowledgeable action is underscored by ways of knowing that weave traditional epistemic games with situated problem-solving actions and discourse into embodied assemblages of functional epistemic games.

The findings of these three studies shed light on the domain-specificity of practice and led to a better understanding of the processes students undergo to “become professionals”. From the perspective of learning through interaction and mediated by knowledge objects, students’ activities in the collaborative projects

demonstrate that knowledge work can be designed in higher education contexts. But, while students find ways to navigate through the complex knowledge of the various domain and practices, as shown in Study 1, they report discrepancies between their initial expectations and the actual experiences during the projects, as pointed out in Study 2. The in-depth look by Study 3 into the mechanisms of functional games that characterize the complexity of professional epistemic practices, underscores the general conclusion that facilitating the enrollment of students into knowledge practices is not necessarily a straightforward endeavor. It requires a subtle understanding of the nature of knowledge practices and strategies that are expected to be learned and taught, and a sophisticated array of pedagogical design alternatives and instructional strategies that have sufficient potential to address the challenges encountered in this context both by students and by those facilitating their learning.

This symposium's contribution to the conference is two-fold. *First*, the symposium attends to issues of relevance to the conference theme in the context of learning in higher education. *Second*, the symposium setup aims to stimulate interaction between the presenters and the audience by: 1) presenting the theoretical and practical frameworks of each of the three studies; 2) depicting the methodology and, especially, the analytic approaches that support the understanding of the examined practices; and 3) by inviting a focused discussion that addresses these three themes and the theoretical, methodological, and practical implications of the presented studies. We intend to engage the audience in the discussion of the contributions, using the three themes to structure the interaction.

## **Collaborative Knowledge Practices in Higher Education: A Comparative Analysis of Student Learning in Two Undergraduate Programs**

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### **Introduction**

This paper examines how students from two higher education programs, teacher education and computer engineering, respectively, become enrolled in and adopt the knowledge practices of their prospective profession through collaborative projects. The study focuses on understanding how students engage in these knowledge structures and practices and how the study programs facilitate the students' participation in these processes.

In recent years, learning in professional domains has been profoundly influenced by developments taking place in a rapidly evolving knowledge society. An essential aspect hereof is the movement to make professional practices more knowledge-based. While a more dynamic relationship between professional fields and higher education brings to the latter the emerging developments of the former, it also brings accompanying challenges. Following the dynamic developments in the work field, characterized by ongoing knowledge production, sharing, and assessment, learning environments are becoming increasingly complex (Nerland, 2012). In the higher education context, this brings about the necessity of introducing students to the knowledge practices of their prospective profession and of supporting them in this process. Students are expected to adopt epistemic strategies and to become actively engaged in profession-specific, knowledge-driven activities. Specifically, students are expected to display active engagement, collaborate with each other, and develop the ability to generate knowledge.

While it is important to understand both the mechanisms by which professional knowledge domains are translated into curriculum and instruction and how students understand and enroll in these practices, few studies have addressed these aspects. This empirical study examines how computer engineering and pre-service teacher students learn and engage in complex learning situations that resemble the knowledge practices of their professional domain. As part of a larger research project, the analyses in this explorative study focus on: a) how students understand and appropriate knowledge structures and strategies specific to their prospective profession; b) how they use and co-construct the knowledge objects that are characteristic to the domains, and c) how they mobilize knowledge resources to inform their projects.

### **Empirical and Theoretical Background**

Recent developments in the knowledge field and new requirements that graduates must fulfill when entering professions have emphasized the need to prepare students for the challenges of knowledge-driven professional work (Healey & Jenkins, 2009; Nerland, 2012). Toward this end, a number of empirical studies (Damşa et al., 2010; Muukkonen & Lakkala, 2009; Zimbardi & Myatt, 2012) have pursued research that conceives of learning as an activity focused on complex problems and distributed project work that resembles professional settings. While these studies provided valuable insights, further research is needed to develop a better understanding of students' immersion and active involvement as participants in processes of knowledge production.

The theoretical framework we build upon follows sociocultural and sociomaterial perspectives on practice and learning. The former emphasizes the social, constructive nature of learning and the fact that activities are mediated by various tools (Valsiner & Van der Veer, 2000; Wertsch, 1991). The later depicts the

mechanisms and arrangements through which knowledge is produced and circulated within expert communities, comprising material aspects (i.e., tools, artifacts, resources), but also procedures, ideas, and attitudes (Knorr Cetina, 1999). In Knorr Cetina's terms, these form the machineries of knowledge construction, which 'make up how we know what we know' (1999, p. 9) within a given domain of expertise and serve to construct knowledge. Emerging from these perspectives, two concepts inform our theoretical and analytic framework. *Epistemic practices* and *action* emerge in this social context in which interaction is paramount. Hence, discursive interaction facilitates the sharing of knowledge and the transformation of meaning potential (Linell, 2009) into "frozen" meaning and traceable knowledge in the context of the collective process. It also allows one to identify the way professional culture is conceived by the participants through their talk. The notion of *epistemic* (or *knowledge*) *objects* is linked to the content of the knowledge practice. These objects can be "material entities or processes" (Knorr Cetina, 1999), which are question-generating and complex entities that have the potential to open lines for inquiry and research. According to Nerland (2012), such objects embody the knowledge of the domains and represent points that students and novice practitioners can use to access the relevant expert cultures and collective knowledge structures. Examining the knowledge objects students engage with or create in collaboration permits the identification of the emerging knowledge; it also allows for the identification of how knowledge within a particular domain is explored and enacted in different contexts.

## Methods

The study was conducted at two bachelor's degree programs in Norway, Teacher Education (TE) at a large university and Computer Engineering (CE) at a university of applied sciences, respectively. These study programs were selected because of their orientation to specific professions and because, at the moment, the programs are undergoing a reform to strengthen knowledge-oriented and research-based learning (Healey & Jenkins, 2009). The TE program is a five-year teacher education program that offers a master's degree and teaching qualification, and it recently introduced curriculum elements aimed at strengthening students' scientific reasoning and analytic competencies. The CE program offers bachelor's degree and master's degree programs in the engineering and information technology field, and it has recently implemented a research-based learning curriculum.

In this research project, the strategy for the empirical investigation considers the gradual immersion of students into the knowledge and practice of the domain. Following this idea, the project started by observing and documenting the instructional and learning practices in a first year bachelor's degree introductory course within each of the two programs: the "Expaed" (TE) and "Web project" (CE). Both are introductory courses and contain varied activities (e.g., lectures, assignments, and individual and group work). The six participating student groups from the Expaed course were required to analyze a case of a pupil displaying learning difficulties by applying the knowledge about learning theories they had gained during the course and by writing a case report. The four participating student groups from the Web Project course were required to design and develop a website, using the programming languages learned during the course (i.e., HTML, CSS, PHP, Java), and to write a project report. Through comparative case studies (Yin, 2003), this first explorative iteration examined learning activities with a focus on existing processes and practices, which will feed into the research design of subsequent iterations.

The dataset reflects the nature and distribution of the activities across the length of the study units and supports an understanding of the interconnections that exist across levels (individual, group, and institutional). The following *data categories* were collected: a) interaction data (video recordings of group meetings, online discussions and correspondence, and field notes); b) knowledge objects (documents, comments, and meeting notes); and c) course documents and lecture materials. The data analysis attempted to capture the complexity of the knowledge work, and it examined the resources and strategies in various contexts. To understand *how* students engage with and act towards appropriating the knowledge practices of their domain, and the way they mobilize and use various resources, we analyzed the groups' discursive interactions within the collaborative work. We employed a technique building on the interaction analysis method, which focused on identifying epistemic actions and object-oriented interaction (Damşa et al., 2010). A document analysis of the groups' knowledge objects and knowledge resources was performed to examine *what* the groups used and constructed in terms of disciplinary knowledge.

## Preliminary Findings and Discussion

The analyses revealed different ways of organizing the collaborative activities at the program level and at the group level. While the TE groups were organized within the context of larger seminar groups and were provided with some incidental guidelines for the collaborative process, the CE groups were organized by the course leader based on their expressed interest, and they were provided with more detailed project work procedures. The TE groups organized their work mainly as face-to-face discussions with some support from online discussions. Their discussions were more explorative, based on experience-based knowledge and local knowledge sources (exclusively course material and teachers' feedback), and they tended to divide the tasks and

the writing responsibilities among the members. The CE groups followed more structured procedures for collaboration and their knowledge construction took place through a series of iterations by way of trial-and-error strategies; they used a validation tool recommended by the teacher to check their produced scripts. These groups accessed and mobilized a range of programming resources available online, and they used online spaces actively to share and discuss their work.

These analyses only allow for preliminary conclusions, but they provide an insight into the specificity of each domain's knowledge and strategies, with differences concerning both the content-related joint work and the procedural aspects of the collaboration. The TE students used rather explorative strategies in approaching the group assignment and they worked towards defining and clarifying the knowledge needed to address the case. The discussions were often focused on how to frame the analysis and report according to the academic standards. Their collaboration appeared to be rather loosely organized and the resources they accessed were domestic to the program. The CE students worked through their collaborative task by employing a structured set of steps and phases, which built on strategies used by software development project teams. In a sense, their work was more organized and thorough, but the use of these prescribed procedures and of the validating tool had a restrictive effect on the exploration potential of the collaboration. In the use of resources, these groups exceeded institutional boundaries and accessed external sources of information. The way TE the students' knowledge objects were developed showed a prevailing strategy of division of labor, while the CE students' objects were, in most cases, developed iteratively, in close collaboration and in an incremental fashion.

To conclude, we consider that these results open up a line of investigation that provides a better understanding of how students enroll in the knowledge structures, practices, and culture of the domain, but with a clear focus on the details that allow them to undergo the process of "becoming professionals". It is interesting to note how the students' knowledge practices resemble characteristics of the two professional cultures, highlighting local embeddedness and the sharing of personal knowledge in teaching and distributed problem solving mediated by procedural standards in computer engineering (Nerland, 2012). The findings show that it is important to capitalize on the domain procedures and structures, but also to find a balance between what a novice student can and must know. Furthermore, the way students participate in the process is influenced by the program that facilitates their interaction with the strategies and objects that are considered to be essential for becoming a knowledgeable professional.

## **Simulating Epistemic Practices of Knowledge Work in Higher Education: Students' Expectations and Experiences**

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### **Introduction**

Current university education faces new challenges in answering the requirements of society to provide students with the competencies that are necessary in the changing work life, such as solving open-ended problems, networking, collaborative creativity, epistemic agency, and digital competencies (Broussard, La Lopa, & Ross-Davis, 2007; Klusek & Bernstein, 2006; Muukkonen & Lakkala, 2009). The present study explored how three courses in university education were set up to engage student teams in the processes of new application and concept development that simulate the workplace practices they would encounter in knowledge intensive companies and organizations. We investigated the kinds of expectations that students have about such courses and how they evaluated their learning experiences. Furthermore, the research contributes by presenting example cases of how teachers assessed the epistemic practices of teams working on open-ended tasks.

### **Learning as Collaborative Knowledge Creation**

A key characteristic present in various models that describe knowledge creation appears to be that collaboration is organized around long-term efforts for developing shared objects, such as articles, models, and practices; for instance in Engeström's (1987) expansive learning, Nonaka and Takeuchi's (1995) organizational knowledge creation, and Bereiter's (2002) knowledge building. Building on previous theories, the triological learning approach (TLA; Paavola & Hakkarainen, 2005) combined three metaphors of learning: the acquisition and the participation metaphors put forward by Sfard (1998) and the knowledge creation metaphor introduced in Paavola, Lipponen, and Hakkarainen (2004). *The acquisition metaphor* of learning addresses the assimilation of prevailing knowledge and an individual's mental models and strategies of learning. Such practices are familiar to anyone taking part in traditional higher education courses, i.e., attending lectures, working on individual tasks, and reading for exams. *The participation metaphor* highlights the adaptation to existing dialogue and to cultural and communal practices. These may be exemplified by a field-training period, where students become familiar with the practices, tools, and cultural knowledge of a particular working community. *The knowledge creation metaphor* and the TLA highlight the object-centered aspect as being central in collaborative learning. The presence of knowledge artifacts, practices, and products—objects—is the rationale for the term “trialogic”.

This approach emphasizes the interaction between collective and individual efforts in working on shared objects as well as on the iterative and sustained character of this process, similar to epistemic objects in professional practices (Knorr Cetina, 2001).

For higher education, this presents the need to promote particular types of competencies, specifically by emphasizing the shared knowledge objects and their iterative development resulting from the interplay between epistemic and regulative efforts during collaboration. In general, teachers have expressed a concern about how the assessment of an individual student's performance can be conducted while the coursework is carried out in teams. This concern stems from a framework of assessment in which the individual is expected to master all the aspects of the assignments, i.e., necessary knowledge and skills as a solo performance. In knowledge creation practices, the process necessitates intensive collaboration, because the participants are required to have complementary skills and knowledge or expertise from different disciplines.

## Aims of the Study

We investigated three higher education courses organized as project work in which multidisciplinary teams of students were assigned to work on open-ended and complex tasks for customers. Such settings are novel to most undergraduate and master's degree students. We examined how students perceived these educational settings and how they described their experiences of collaborating with members of their teams and with the customers. Furthermore, the paper addresses questions about how to evaluate collaborative outcomes and processes. Specifically, the research examined the following questions: 1) What kinds of expectations did the students express for the course and its learning outcomes? 2) What kinds of experiences did the students report after the course? and 3) How did the teachers set up the assessment of the collaboration efforts and the outcomes?

## Methods

Three courses were designed by the teachers and their collaborators from professional organizations (course customers) to engage undergraduate students in complex knowledge creation processes in multi-disciplinary teams. *Case 1*, the "Application Development Project" (ADP) course was organized at the Metropolia University of Applied Sciences, Finland, and it ran from September 2009 to March 2010. The study participants were undergraduate students ( $n=50$ ) and teachers ( $n=4$ ) from three training programs: media engineering, industrial management, and media and communications. In addition, four customer organizations were involved. The course was purported to teach students about the development of business ideas and related services, and multimedia products. The students worked in 11 multidisciplinary teams of three-to-six members to develop business plans, user stories, marketing strategies, and software architecture in order to come up with operational business application. Teams' working documents, based on templates pre-structured with domain specific conceptualizations, were presented and discussed during weekly steering group sessions.

*Case 2*, the "Tax Office Exercise" (TAX), was a course on advanced themes in project management that ran from March 2010 to May 2010. It involved students in business and psychology domains ( $n=30$ ) and academic staff ( $n=5$ ) from the University of Helsinki and the Aalto University School of Economics. The students were asked to analyze the characteristics of different groups of taxpayers and to create, on the basis of this analysis, concepts for future research projects for the Finnish Tax Administration (the customer). The course aimed to be a practical way of learning virtual project management practices: managing a subcontracting network, team building, coordinating tasks and responsibilities, managing a complete project in a short timeframe, and using collaboration technology. The students worked in eight multidisciplinary teams (three-to-five students per team).

*Case 3*, the "Project Work Course" (BIO), was held at the Faculty of Biological and Environmental Sciences, University of Helsinki. Students ( $n=15$ ) were divided into three teams, each of which worked on a customer project in the field of biosciences. The course, tutored by teachers ( $n=3$ ) lasted from September to December 2012. The aim was to learn to plan, manage, and report on a project work for a customer. Initial project training provided models for organizing the process. During joint meetings the teams presented their work results and received feedback.

Data for the study consisted of the students' responses to open-ended reflective questions as well as the teachers' assessments of teams (and individuals). At the onset of the course (pre), the students were asked to answer the following questions: 1) What thoughts and expectations do you have about the course, its forms of studying, and its goals? and 2) What do you want to achieve by participating in the course? After the course, the students were asked to evaluate their experience by answering the following questions: 1) How would you characterize your overall experience(s) in the course? 2) How would you characterize your own participation and activity during the course? Please justify your answer. 3) What has been positive or impressive about the course? and 4) What has been challenging or disturbing in the course? The students were also prompted for other comments.

The qualitative data was analyzed inductively (Chi, 1997; Muukkonen, Lakkala, Kaistinen, & Nyman, 2010) by segmenting the responses into ideas. Several rounds of category development with the ATLAS.TI

software were carried out. A categorization of expectations and experiences was first data-grounded and then aligned with the TLA, when applicable.

## Results and Conclusions

*Students' pre-course reflections* ( $f=303$ ) indicated that the students expected to learn collaboration practices, independent teamwork and planning, new knowledge, and knowledge about the nature of work-life and expert-like practices. By taking the course, they hoped to gain contacts with employers and secure an employment advantage, and knowledge, practices, and skills for work-life; they also hoped to gain experience with project work and to strengthen their management competencies.

*After the courses* ( $f=401$ ), the students reported that they had gained various kinds of knowledge and competencies. Further, they reflected to have learned how to take initiative, create new ideas and practices in teams, and project management and coordination. They especially valued that the courses included interesting assignments and outcomes, teamwork, projects, and real customers. Students critiqued the high complexity of the course assignments and the unclear initial goal framing and schedule; some of them criticized the virtual collaboration environment. Teamwork, in particular, generated numerous reflections. When teamwork had not advanced optimally in the team, the members reported frustration, problems with team coordination and scheduling, and uneven participation; when teamwork had advanced well, the students reported achieving creative outcomes.

We identified three foci in *teachers' assessment frameworks*: regulative documentation-based (e.g., team formation, management, participation), collective engagement-based (e.g., peer review entries, communication), and knowledge-based assessment (e.g., quality, innovativeness, and customer feedback).

A comparison of the expectations and experiences suggests that, before the course, the students wanted to gain knowledge of expert practices in real projects with customers. After the course, the students reported details about the dimensions of initiating and sustaining multidisciplinary collaboration and advancing the shared objects. Furthermore, several teams would have benefitted from more support for initial goal framing and team formation. The findings highlight that students valued the engagement in these types of learning practices, but the findings also call for more research on the ways to pedagogically design the complex assignments and to scaffold and assess the development of corresponding competencies.

## Epistemic Games for Knowledgeable Action in Professional Learning

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### Introduction

This paper reports research in the field of professional education and professional expertise that combines epistemic practice and epistemic fluency perspectives (Goodyear & Zenios, 2007; Knorr-Cetina, 1999; Morrison & Collins, 1996) to uncover characteristic ways of knowing that future professionals learn to enact when they are performing complex knowledge-demanding professional tasks. We extend epistemic forms, frames and games theories (Collins & Ferguson, 1993; Perkins, 1997; Shaffer, 2006) into the area of *situated professional work*. We identify six categories of epistemic games for knowledgeable action and learning in professional education. These emerge from our investigation of the nature of epistemic games that are embedded in tasks that university students complete in professional practice courses. Our findings show that such tasks go beyond *formal epistemic games* and the construction of mono-professional knowledge. Rather, these tasks require students to engage in new kinds of inquiry that enhance their situated understanding and inform the actions of others. These situated and distributed ways of knowing weave traditional epistemic games with professional problem solving, various modes of discourse and socio-material practices - making embodied assemblages of *functional epistemic games*.

### Background

Research in such diverse fields as sociology, anthropology, cultural studies, psychology and information technologies has acknowledged that some important aspects of human behavior can be characterized by certain structures and patterns that appear repeatedly in their discourse and actions, including human "ways to think". Collins and Ferguson (1993) and others (Perkins, 1997) have argued that almost every domain of human activity has a set of such characteristic forms of knowledge and ways of knowing, which guide skillful investigations in those domains. They refer to these schematized kinds of knowledge as "epistemic forms", and the ways of working with specific epistemic forms as "epistemic games". As an example, they showed that science and history have a set of epistemic forms and epistemic games for conducting structural, functional and process analyses, including such forms as diagrams for spatial decomposition, tables for comparing and contrasting, and flowcharts for identifying causal relationships. They argued that these specialized but shared ways of knowing

constitute important domains of expertise. People who are good at recognizing and participating in a range of epistemic games are said to possess “epistemic fluency”: they are flexible and adept with respect to different ways of knowing about the world (Morrison & Collins, 1996). As Collins and Ferguson (1993) suggested, “Systematic analyses of theories and inquiry strategies in the different disciplines are needed to build a detailed theory of the different epistemic forms and games <...> and to identify other forms and games that sophisticated inquirers use.” (40).

Epistemic games are rarely taught explicitly and little is known about the variations across disciplines. Professions are inherently *multidisciplinary* fields. They construct their epistemological foundations by adopting generative frameworks from multiple academic disciplines, and also by creating their own ways of representing knowledge, structuring inquiries and validating claims (Goodyear & Steeple, 1998).

In the learning sciences, analyses of epistemic forms and games have focused on *generic* structures and ways of knowing that are recognized in various disciplinary discourses as tools for generating the community’s knowledge. As Perkins (1997) argued, epistemic games must have explicit epistemological agendas of discovery, verification and knowledge sharing. In short, these games should lead to what Greeno (2012) called, “formal knowledge.” However, *formal knowledge* is not the same as the *functional knowledge* that professionals use to make sense of the world (Greeno, 2012) and *formal ways of knowing* do not necessarily correspond to *functional ways of knowing* that professionals use when they “read” an encountered situation and decide how to act (Hutchins, 2012). In fact, the nature of the functional epistemic games, which professionals play when they generate the situated knowledge that informs their actions, is little understood.

## Method

Our study included two stages. In the first stage, we investigated 20 professional practice courses that aimed to prepare students for externships in workplace settings in five professional fields: pharmacy, nursing, social work, school counseling and education. The dataset included interviews with 16 academics (faculty) coordinating these courses (up to 3 interviews per course) and a comprehensive collection of course materials, including tutorial handouts, specifications of assignments, and samples of completed tasks. The interviews focused on course designs, with particular attention to the design of tasks in which students were expected to learn and demonstrate certain workplace-related capacities. In total, we analyzed 24 tasks. Most included enactments of professional knowledge and skills (e.g., medication-dispensing role plays, children’s behavioral assessments, and teaching various lessons) and the production of related artifacts (e.g., assessment reports and lesson plans). To elucidate the epistemic games that students were expected to master, we adopted a combination of cognitive task analysis (Crandall, Klein, & Hoffman, 2006) and epistemic interviewing techniques (Brinkmann, 2007). We used the course resources as prompts for interviewing the academics and, through detailed questioning of how and why various artifacts were used and produced, we aimed to depict generative frameworks that students were expected to use for completing the tasks. During the analysis, we simultaneously re-analyzed collected artifacts and interviews, and recreated the main features of characteristic patterns around which students were expected to structure their situated inquiries. In the second stage, we complemented and corroborated the outcomes from the first stage by conducting observations of tutorials in a pharmacy course (3 tutorial groups taught by 3 academics over a 6 week period) and observing students’ independent group work in a teacher education course (2 groups).

## Results and Discussion

Our findings revealed six main classes of functional epistemic games that we call: *propositional games*, *situated problem-solving games*, *meta-professional* and *trans-professional discourse games*, *translational public discourse games* and *weaving games*. Propositional games are most like the epistemic games already documented in the literature, so we do not describe them here (see Markauskaite & Goodyear, forthcoming).

*Situated problem-solving games* are played during the investigation and solution of specific professional problems, such as conducting reviews of medications used by patients with multiple diseases in order to identify possible issues, with an aim of proposing better medication plans (pharmacy), or designing lessons for classroom teaching (education). Elaborated problem-solving games could combine different aspects or stages of problem solving or design, which by themselves could be quite complex epistemic games. For example, a typical medication review includes *investigation* of a situation; *processing* of coded information using various conceptual tools; *prioritization* of findings using various professional heuristics and *development* of a reasonable, knowledge informed, practical solution. Overall, problem-solving games resemble professional practices that Goodwin (1994) calls “professional vision”. The guiding epistemological purpose is to enhance situated understanding of the specific problematical situation by structuring things and events in a particular professional ways and, consequently, offering feasible solutions.

*Meta-professional discourse games* are usually played with other professionals within a broader professional field, in order to evaluate various professional products, actions or events. They involve various deconstructions, evaluations and reflections, such as analyses of new medications, evaluations of teaching

resources, and reflections on one's practices. In contrast, *trans-professional discourse* games are played when professionals from different fields jointly work on complex problems. These games range from simple sharing of relevant information, such as writing a referral for a specialist consultation, to engaging in joint problem-solving conversations, such as medical case conferences for discussing identified issues and deciding about possible interventions. The primary epistemological function of such multi- and trans- professional discourse games is to re-describe professional knowledge from the perspective of others who (epistemologically) are outside the game that produced this knowledge. These games do not always produce new knowledge, but enhance joint knowledgeable action by creating links between different professional knowledges and actions.

*Translational public discourse games* are played when professionals engage in interactions with people who broadly could be described as "clients". Such games involve common patterns of discourse that professionals find effective for collecting relevant information and communicating their reasoning to non-professional audiences. For example, these games are evident in pharmacists' communication strategies with clients – e.g. when they gather relevant information about health conditions before dispensing a new prescription and characteristic ways of writing instructions on a box with medications. Such games are informed by the epistemological agenda of extended knowledgeable action (Clark, 2011). They transverse the boundaries between professional and everyday ways of knowing and thereby extend professional knowledgeable actions to the actions of others in the everyday world.

*Weaving games* are played in dynamic action and involve continuous intertwining of meaning-making, social interaction and skilled performance. They range from very specialized games that can require fine-tuned physical skill - such as strategies for capturing all the spelling mistakes in a literacy test - to quite generic games that require complex coordination of various general and specialized strategies and skills - such as a teacher's weaving of various strategies for identifying students' learning challenges, choices of appropriate translational games, and continuous fine-tuning of voice pitch and movement in the classroom. Weaving games usually blend multiple epistemological goals, which are adjusted and remixed in response to the unfolding situation.

## Conclusions

The findings show that *functional* epistemic games for knowledgeable action and enrolment extend beyond the standard epistemological agendas of *formal* epistemic games that generate propositional knowledge. These professional inquiries follow patterns of pragmatic problem-solving, sensible decision-making and embodied situated action. They weave various games into larger assemblages of characteristic epistemic practices. Such weaving games involve continuous adjustment of actions in response to emerging situations and require fluent coordination of professional perception, problem solving, bodily skill, and discourse. Further, intelligent professional behavior relies on ways of knowing that not only expand one's perception of the problematic situation and improve one's personal understanding, but also on ways of knowing that extend one's epistemic activity to the environment, including social others, and enhance overall micro system's capacities for knowledgeable action. Meta- and trans-professional discourse and translational games play important roles in such extended knowledge activity. These discourse games require re-articulation of professional knowledge in various professional and non-professional epistemological frameworks, the capacity to recognize and switch between various traditional kinds of discourse, and also a professional capacity to play skillfully special kinds of games for translating knowledge.

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# Becoming More Mathematical: New Directions for Describing and Designing for Positive Dispositions Toward Mathematics

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**Abstract:** This symposium brings together researchers interested in studying mathematical proficiency through a focus on students' dispositions toward mathematics - their ideas and affect about mathematics and their patterns of engagement with it. While dispositions are useful for connecting important aspects of students' proficiency, they are also broad and challenging to operationalize in empirical contexts. This symposium aims to promote dialogue around the meaning of dispositions as an analytic construct and to explore their relationship to other constructs relevant to helping learners become mathematical. We also aim to demonstrate that different methodological orientations allow us to see different aspects of what we all agree to call "dispositions". We present empirical work which address two foci within research on dispositions –operationalizing in ways that enable documentation in a classroom context, and designing learning environments which foster positive dispositions to mathematics - in addition to a piece that bridges work between the two.

## Introduction

Proficiency in mathematics is a longstanding but elusive goal for education. Many students fail to reach proficiency in math, and indeed do not move past introductory algebra. This lack of mathematical proficiency has consequences for school and career choices. Researchers now agree that becoming proficient in math depends at least partially on how students' come to see themselves as math learners, what they think it means to do math, and their patterns of engagement with mathematics. In recent years, the construct of *dispositions* has emerged to refer to this collection of ideas and attitudes about mathematics and math learning. The idea of dispositions places social, affective and motivational factors as central to what students learn and who they come to be as mathematical thinkers (Gresalfi, 2009). Research on dispositions explores the interconnections among students' patterns of thought, affect and action and the classroom environment through a focus on moment-to-moment interactions and longer-term patterns over time (Gresalfi, 2009; Gresalfi & Cobb, 2006). While the construct of a disposition is useful to connect students' ideas and affect about mathematics with their patterns of engagement, it is also broad and challenging to operationalize in empirical contexts. Also, several related lines of research address similar issues with different terms, such as identity (Langer-Osuna, accepted; Nasir 2002; Sfard & Prusak 2005), goals (Nasir, 2002), affect (Sengupta-Irving & Enyedy, under review), and social and intellectual authority (Langer-Osuna & Iuhasz, 2013; Yackel & Cobb, 1996).

This symposium brings together researchers studying mathematical dispositions, with the goal of promoting a dialogue about the meaning of dispositions as an analytic construct, and to explore its relationship to other related constructs. There are two related foci regarding students' dispositions, each requiring different types of research. The first focus is: How do we operationalize dispositions in ways that enable their documentation in a classroom context? The second focus is: How can we design learning environments to foster positive dispositions to mathematics?" Our symposium addresses both of these issues through presentations that address each foci, accompanied by commentary from two discussants who are well-versed in issues of promoting productive engagement with content.

## **Background**

Mathematical proficiency, as defined in the new Common Core State Standards for Mathematics (CCSSM), includes being able to innovate, solve problems and engage in mathematical discussions (CCSS, 2011). Yet international and national assessments indicate that many students are not reaching advanced levels of problem solving (Gonzales et al., 2008; U.S. Department of Education, 2011). In addition, there is growing concern that many students are developing a passive, disengaged relationship with mathematics (Boaler & Greeno, 2000) which stands in stark contrast to the confident, flexible use of mathematics required for advanced mathematical work (Boaler, 2008). It is becoming clear that focusing instruction on students' learning of skills and knowledge alone greatly underdetermines their subsequent success in mathematics (Franke, Kazemi, & Battey, 2007). There are important aspects of the mathematical thinkers that students are becoming, including their attitudes toward mathematics, their ideas about what it means to practice, and their patterns of engagement with mathematics, which are increasingly recognized as important aspects of their development and an emerging focus for research.

Building on a socio-cultural perspective to learning, which focuses on the role of social interaction and cultural history in individual learning (e.g. Vygotsky, 1978), we argue that becoming a strong mathematical thinker is as much a process of acquiring "habits and dispositions of interpretation and sense-making" (Resnick, 1988, p. 58) as about learning particular skills and knowledge. From a sociocultural perspective, students develop understanding of what it means to do mathematics through their interactions with others, and these interactions take place within and are shaped by the practices of a specific community over time. As students are exposed to and take up specific ideas about the value and purpose of math and what it means to practice mathematics, they develop an orientation to mathematics themselves. The development of this orientation, situated within the context of the classroom, is the primary focus of this symposium.

This symposium aims to bring together several lines of related research that address aspects of dispositions. One of the goals of the symposium is to provide an opportunity for cross-pollination of ideas both between presenters and attendees. A second goal of the symposium is to demonstrate that different methodological orientations allow us to see different aspects of what we all agree to call "dispositions". The construct of dispositions is useful in focusing on important factors of students' developing mathematical thinking. At the same time, understanding, describing and designing for the development of productive dispositions will require a joint coordinated effort, which requires dialogue and understanding across related lines of work.

## **Presentations**

We begin with work that addresses the first focus of operationalizing dispositions in the classroom. Two presentations focus on empirical descriptions of students' relationships with mathematics and relate this to their engagement in a classroom environment. Tesha Sengupta-Irving and Noel Enyedy will present findings from a teaching experiment with 5<sup>th</sup> grade students in which they examine contrasts in affect between groups who had the guided vs. self-directed pedagogical approach, and relate contrasts in affect to students' patterns of disciplinary engagement. Melissa Kumar will present findings from a year-long study with 3rd grade students in which she relates students' reported adoption of four positive goals for learning with their patterns of engagement in problem solving as a window on their dispositions, looking specifically at how students with different goal profiles varied in patterns of engagement. We then turn to the second foci, designing to support development of positive dispositions. Melissa Gresalfi will describe a design experiment with 8<sup>th</sup> grade students. She examines how the different design of tasks, one which asked students to practice using a formula and one which asked them to invent a formula to describe density, supported different forms of engagement, specifically decision making during problem solving. The final presentation bridges the two research foci, beginning with descriptions of students' dispositions and moving to more recent work describing a design experiment based on findings about students' dispositions. Jennifer Langer-Osuna will present results of an analysis of how social and intellectual forms of authority related to different types of engagement in problem solving. She then reports on how a design experiment in which each student was offered opportunities to take on the group leader role supported more equitable opportunities for students to construct forms of authority.

## **Symposium Structure**

The session will take the form of a traditional 90-minute paper session, with brief remarks by the chair followed by twelve minutes per paper presentation. We have included two discussants with different perspectives in our proposal because one of our goals is specifically to facilitate dialogue around the overlap and contrast of different approaches to study what we agree to call dispositions, and we believe that this decision will facilitate a richer session to this end. Each discussant will have 15 minutes to respond to the papers, after which we will open the space to a discussion with the audience. Our first discussant, Anna Sfard, is a leading authority on mathematics discourse in thinking and learning. She has examined the relationship between students' identities and their engagement with mathematics, illuminating the way that group narratives shape the dispositions of

individual students (Sfard & Prusak, 2005). Our second discussant, Kris Gutierrez, is a leading authority on literacy and learning. Her description of the 3rd space, where the narratives and identities of the teacher and students can coexist, has facilitated the examination of how students' actively take up or repurpose available ideas, values and discourses within the classroom (Gutierrez, Rymes & Larson, 1995). Each discussant will speak to common themes in the papers, offer commentary on areas for additional research and bring up questions to be pursued in the general discussion.

## **Smiles Don't count: A Case Study Unifying Disciplinary Engagement with Dispositions in the Study of Mathematical Learning**

Tesha Sengupta-Irving, University of California, Irvine and Noel Enyedy, University of California, Los Angeles

Whether seen as a triumph of Western traditions separating and valuing cognition over emotion, or the logical consequence of increasingly technocratic systems of accountability in public schools, the national discourse of achievement has grossly obscured the importance of advancing student thinking *and* cultivating positive feelings toward a discipline (Vadeboncoeur & Collie, 2013). In mathematics, we risk a generation of learners who score among the highest averages in achievement but who are also among the most negative in their attitudes toward the discipline, as seen of other countries in international and comparative studies (e.g., Beaton, Mullis, Martin, Gonzalez, Kelly, & Smith, 1996; Mullis, Martin, Gonzalez, Gregory, Garden, O'Connor, Chrostowski, & Smith, 2000). This inverted relationship – achievement without enjoyment – is both learned and problematic: innovation is cultivated through rewarding curiosity and effort, not disinterest and detachment. This risk is underappreciated in the national discourse on mathematics education – whether looking to the National Research Council's five strands of mathematical proficiency (Kilpatrick, Swafford & Findell, 2001), or math practice standards of the Common Core Standards (CCSI, 2011), evaluating if students *like* learning is rarely discussed. Recent studies on the notion of dispositions in mathematics education (e.g., Boaler & Greeno, 2000; Gresalfi, 2009), however, demonstrate the potential for research in the learning sciences to anticipate this risk, and identify means of mitigating it.

This paper draws on a 10 day teaching experiment comparing two pedagogical approaches (one guided and one self-directed) used to teach data and statistics to 5<sup>th</sup> grade students (n=52). This study took place in a socioeconomically diverse elementary school in a large urban center in California. The progressive school encouraged teachers to adopt research-based teaching practices. The teacher, an African-American woman, had fifteen years of teaching experience in mathematics.

Elsewhere, we have described learning results for the teacher (Sengupta-Irving, Redman, & Enyedy, 2013) and students (Sengupta-Irving & Enyedy, under review). Of relevance, we found that students in both treatments (n=27, n=25) improved in their proficiency in data and statistics, but reported significantly different orientations in how much they liked learning the lessons. In this paper we take up the methodological question that emerged as a consequence of this result: How can we use video-based interactional analyses to characterize why students were “liking” what (or how) they were learning? We see this methodological question as part of the larger project of promoting research that uniformly attends to disciplinary engagement and cultivating positive affect among mathematics learners.

In the study, we used video-based interactional analyses to explore why students had different affective responses to treatments in the experiment (with no corresponding difference in performance). In the process, we made several important methodological and practical decisions in order to operationalize “liking” that could then be characterized and quantified comparatively. What began with a tongue-in-cheek discussion of ‘Can’t we just count the smiles?’ evolved into a complex constellation of cultural, disciplinary, and pragmatic decisions about how we characterize students “liking” (or not) what they are learning. Our paper discusses the evolution and results of these discussions, which directly relate to a guiding focus of the symposium: *How do we operationalize dispositions for individuals in a classroom context?* In our work, we narrow the theoretical scope of dispositions to focus specifically on how we characterized, contextualized, and quantified students’ engagement in the mathematical tasks for each treatment. Moreover, we speak to patterns of engagement within the context of a 10-day pedagogical experiment, and not patterns over time and across learning contexts. We drew significantly from Engle and Conant’s (2002) principles of productive disciplinary engagement, and developed our own measures of student autonomy (i.e., continuous activity without adult intervention) and on-task behaviors, which were grounded in the design of the experiment. What results is a depiction of learning that inextricably links affect and patterns in disciplinary engagement to the classroom context and organization of learning therein.

This case study offers a model of how research can promote a perspective on learning that draws together students’ disciplinary engagement and affect toward the discipline. We discuss the design of learning environments and tasks that support this perspective, which speak both to research and teaching. Finally, we raise several questions and potential directions for future studies in the learning sciences that can help mitigate

the widening gap between promoting disciplinary proficiency and developing disciplinary dispositions in our national discourse.

## **Elementary Students' Dispositions, Goals and Engagement in Problem Solving in Mathematics**

Melissa Kumar, University of California, Los Angeles

Mathematical proficiency by today's standards includes being able to innovate, problem solve, and collaborate around challenging problems. One important question is, What drives students' engagement in these activities? In this paper I describe work from my dissertation in which I build on the construct of dispositions to explore the goals that motivate student's engagement in math class, such as wanting to understand concepts or solve challenging problems. Studying students' goals facilities more specific insight into the motives that students have for participating in mathematics, and how their relationships with mathematics emerge from a specific cultural practice. I focus on 3<sup>rd</sup> grade students because research points to an important shift (often negative) in perceptions of self-efficacy and value of mathematics at this age (Eccles, Wigfield, Harold, & Blumenfeld, 1993). I examine students' adoption of four positive goals for mathematics and relate this to engagement in problem solving as a window on their dispositions to mathematics. The study was guided by the questions, (1) What goals are appropriated by the students? And to what degree do these goals align with the values of the reform-oriented mathematics education community? And (2) How do different profiles of goals relate to students' engagement in problem solving?

Goals have been used as a way to understand the link between cultural activity and individual cognition beginning with early Soviet psychology (Wertsch, 1981). More recent work has examined goals as a mediating link between society, culture and thinking (Saxe, 1999, as cited in Nasir, 2002) and to understand the concurrent development of students' identities, mathematical goals, and learning in informal mathematics practices (Nasir, 2002). Nasir (2002) argues that goals are critical to understanding learning because humans act specifically to accomplish goals in social activity, and these goals "help structure the nature of the thought and problem solving of individuals" (p. 216). The current study builds on the view that goals emerge through participation in cultural practice, and links goals both to the larger construct of disposition as well as the moment-to-moment problem solving activity of individuals. I contend that studying students' goals can shed light on aspects of their dispositions because the more "enduring" aspects of dispositions—the "ideas about" and "perspectives on" mathematics—must be transformed into engagement in the moment. Goals are a likely construct to mediate this transformation from ideas and perspectives to action and thus may illuminate what students think is valued in mathematics in their classroom, how they appropriate these available goals, and how aspects of the context and dispositions combine to direct student effort in problem solving. Looking at students' goals is therefore a useful lens in which to examine students' dispositions in a mathematics classroom.

While there are multiple goals that drive students' engagement in math class, I focus on four goals that I derived from the math education and educational psychology goal-orientation literature, the CCSSPM, and from descriptions of the practices and values of mathematicians. The goals are understanding the mathematics at a conceptual level (CCSI, 2011; Boaler, 2008), solving challenging problems (CCSI, 2011; Lampert, 1990), exercising agency and creativity in solving math problems (CCSI, 2010; Boaler, 2002), and being viewed as a valuable contributor in classroom discussions (CCSI, 2010; Boaler, 2002; Boaler & Greeno, 2000). These goals are meant to represent the motivation that students would have as a part of a positive disposition to mathematics in alignment with the reform-oriented mathematics education community. The position of this paper is that all of these goals are important to be successful in mathematics practice. These goals form the framework of my exploration of students' reported goals and observation of their patterns of engagement in problem solving.

I will report on data that was collected in a 3<sup>rd</sup> grade classroom (n=27) over the 2013-2014 school year. I selected the site because of its progressive, constructivist teaching philosophy and because it follows the principles of Cognitively Guided Instruction (Carpenter, Fennema, & Franke, 1996; Carpenter, Fennema, Franke, Levi, & Empson, 1999) a curriculum that attends both to fostering problem solving and the dispositions of students to be problem solvers. The teacher embraces these philosophies and draws on her CGI training in her instruction. Data sources include a video record and field notes of class activities, with a focus on six case study students during problem solving, student surveys and interviews, and student work. Video was collected throughout the year, and surveys and interviews were administered three times during the year. I focused on collaborative problem solving because it is central to the practice of mathematics and because it affords multiple opportunities to see students pursue goals in specific conditions. The survey focused on students' adoption of the four positive goals and two goals of relative performance using a Likert-type scale from "not at all true" to "very true". The interview focused on clarifying and expanding survey responses and asking students about their problem solving using video clips from class.

To characterize students' engagement in problem solving, I identified problem solving sessions that were challenging, open-ended, and had multiple possible solutions from the first and second half of the year for

three case study students. I identified decision points and created a “roadmap” for each problem, with particular attention to students’ entry into the problem. Decision points included: new information from other groups, peers or the teacher, roadblocks in problem solving that prompted the student to change or modify the strategy, revisions to the group work plan, and moments of insight. I then characterized students’ engagement at each decision points, including the degree to which they showed perseverance, creativity and flexibility in their thinking.

Preliminary analysis of survey results suggests that students in the class did indeed have different goal profiles. To create students’ goal profiles, I first created composite scores for each goal, and then I categorized students by how many of the goals had a high, medium or low score. Nine students were categorized as “high” because they had high scores for 3 or 4 goals. Three students were categorized as “medium high” because 2 goals had high scores and the other two were medium or low. Seven students were “medium” because they either had medium scores for all goals, or a mix of high and low scores, and seven students were “low” because they had mostly low scores for each goal. These preliminary results will be compared with students’ survey results in the middle and end of the year. In addition, I will present preliminary analysis of the connection between students’ goals and pattern of engagement in problem solving in the classroom based on the video analysis described above.

This presentation describes empirical connections between the goals that students have for mathematics, specifically the four goals considered positive for mathematical proficiency, and their engagement in problem solving as a window on their dispositions to mathematics. In doing so, I address the first goal of this symposium, which is to address methodological issues of operationalizing dispositions in a classroom environment. In addition, this paper presents a unique approach to focusing on students’ motivation in math class by proposing four goals synthesized from the reform-oriented mathematics education community, and connecting student’s adoption of the positive goals to their engagement in problem solving. This is significant for those who wish to understand what motivates student engagement in math class in order to design instruction that promotes understanding and supports positive dispositions to mathematics. Clarifying what positive goals for mathematics look like, how they translate into problem solving actions, and how they relate to other aspects of the classroom ecosystem is valuable to educators, researchers and parents, as well as students in their later years.

## Framing Engagement Through The Design of Tasks

Melissa Gresalfi, Vanderbilt University

Student mathematics learning and achievement is a topic of significant study and concern in both the United States and around the world. Although a range of issues is often discussed, one that yields some of the greatest debate regards what and how students should know and understand mathematics. The past twenty years have brought technological innovations that have changed the world as we know it. Continuous access to online information has supported a transformation of the relationship between individuals and knowledge; with information so readily accessible, people have been repositioned to move beyond *acquisition* of facts to consider when to access those facts, interrogate them, and integrate them into activity. For these reasons, knowledgeable participation in mathematics must involve more than proficiency using key procedures. Instead, knowledgeable participation must involve engaging in acts of decision-making, determining which procedures enable the resolution of defensible solutions, how, and why. Lampert (1990) has defined such mathematical activity as being “courageous and modest in making and evaluating [one’s] own assertions and those of others, and in arguing about what is mathematically true” (p. 33).

It is clear that supporting students to engage with mathematics in this way is not simply a matter of teaching them more mathematics. Instead, it is crucial that students have opportunities to learn new content in ways that are consistent with how we actually want them to use that information (Boaler, 2000; Bransford & Schwartz, 1999; Greeno, 1991; Lave, 1997). When creating new curricula, it is therefore crucial that designers attend not just to the content goals of the unit (the mathematical ideas you want students to learn and understand), but also dispositional goals of the unit (how you hope students will engage). This does not mean that becoming a successful engineer, for example, requires learning all mathematics at the elbow of a practicing engineer. Instead, this suggests that the kinds of *practices* that a practitioner is expected to leverage (such as experimenting, reviewing, collaborating, justifying, testing, and inventing) are the practices engaged in during the learning experiences.

In my work I have found it productive to consider how students are engaging information as an explicit framework to both support design and to analyze student learning (Gresalfi & Barab, 2011; Gresalfi & Barnes, 2012; Gresalfi, Barnes, & Cross, 2013). Specifically, we have focused on four forms of engagement with mathematics: Procedural, Conceptual, Consequential, and Critical. Although procedural and conceptual engagement are familiar ideas, consequential and critical engagement are not. *Consequential engagement* involves recognizing the usefulness and impact of disciplinary tools; being able to connect particular solutions

to particular outcomes. Finally, *Critical engagement* involves choosing particular tools and interrogating their impact in attaining desired ends. Related to consequential engagement, critical engagement captures the decision making involved in problem-solving, and at some level involves critiquing the method itself in relation to the particular context in which it's being used.

In this presentation, I draw on this framework to consider how the design of particular tasks frame students' engagement with problems related to understanding ratio and density, drawing on data from a study reported by Schwartz, Chase, Oppezzo, & Chin (2011). This study included students in four different 8<sup>th</sup> grade classes taught by the same teacher. Students in two of the classes completed a series of tasks that allowed them to practice using the formula for density across three different kinds of worksheets (the "tell" condition). Students in the other two classes used the same worksheets, but were instead asked to "invent an index" that could describe the density of different items (the word density in this case was not used (the "invent" condition). In analyzing these data, Schwartz et al. (2011) found that while students in both groups demonstrated proficiency at using the given formulas on word problems (a "near transfer" task); students in the "invent" condition were able to transfer the underlying idea of ratio to new content (a "far transfer" task). The analysis reported here focuses on videotapes of groups of students in both conditions solving these tasks over three days.

Student interaction was coded using both apriori and emergent schemes; drawing on coding from previous work (Gresalfi, Barnes, & Cross, 2012; Gresalfi & Barnes, 2012), we classified students' engagement with the task as either procedural, conceptual, consequential, or critical. We then examined instances of student talk in relation to these codes in order to better understand what about the task was contributing to their engagement. Our analysis specifically considers the affordances of the tasks for supporting different forms of engagement, and considers whether and how those different affordances are realized through the group's interactions. In so doing, we consider both how students' engagement changes over the course of three days, and how that engagement is framed by the tasks they are working on.

## **Supporting the Construction of Student Authority During Collaborative Mathematics Problem Solving**

Jennifer Langer-Osuna, University of Florida

The proposed presentation will focus on how students construct relations of authority in interaction, and the ways in which differential authority relations serve to marginalize or privilege particular students' engagement in collaborative mathematical problem solving. In particular, I will present preliminary results of a design experiment meant to structure how students become positioned with forms of authority in an effort to support equitable and productive engagement in collaborative mathematics activity.

Students positioned with intellectual authority participate more frequently in small groups, are more able to gain access to and hold the conversational floor and decide what is correct, tend to be seen as contributing more meritorious ideas, and become more influential than students perceived as having less intellectual authority (Engle, Langer-Osuna, McKinney de Royston, in press; Inglis & Mejia-Ramos, 2009). And though forms of student authority other than intellectual authority are rarely studied in mathematics education research, emerging research is beginning to show that social forms of authority—in particular being positioned with the right to issue directives to peers—is fundamentally related to both student engagement levels and the development of intellectual authority itself (Langer-Osuna, 2011; Langer-Osuna & Iuhasz, 2013).

## **Designing for Equitable Distribution of Intellectual and Directive Authority**

The proposed presentation builds on the results of a previous analysis focused on how social and intellectual forms of authority relate to the construction of particular mathematical solution paths (Langer-Osuna & Iuhasz, 2013). Results highlighted how particular interactions supported the construction of forms of authority – both the social authority to issue directives to peers and the intellectual authority of being positioned as a credible source of information – and its role in determining whose ideas were taken up as part of the solution path. In this presentation, I briefly present and then build on these results to frame a new design experiment meant to support more equitable opportunities for students to construct forms of authority, such that multiple student ideas are attended to, debated and considered as potential contributions to a problem's solution path.

The study context is a weekly afterschool math program for third through fifth graders at two public elementary schools with diverse student populations. Students worked individually and in groups of three. Below I detail how we framed the learning context for interactions around both intellectual and directive authority.

Preliminary video-based interaction analysis will be presented, focused on how students positioned themselves and one another with forms of intellectual and directive authority, how those positionings were taken up by peers, and their effect on patterns of engagement and whose ideas were taken up as part of the solution path. Results will be illustrated through vignettes of how students constructed forms of authority and

the ways in which these positions affected both student engagement and the construction of particular mathematics solution paths based on what (and whose) ideas became influential.

### **Fostering and Examining Positions of Intellectual Authority**

Group participation structures such as distributed expertise (Brown et al. 1993) can support the development of student intellectual authority. In classrooms that utilize distributed expertise, students are treated as researchers who gather, analyze, and share information about a particular topic, gradually developing expertise in that specialty area, increasing the likelihood that all students become positioned with intellectual authority.

Here, a key element of the mathematical activity is an explicit focus on representations as vehicles for mathematical thinking and communication. The design experiment created opportunities for each member of each student group to develop expertise in a particular representation to then bring back to the collaborative problem-solving process.

### **Fostering and Examining Positions of Social Authority**

Despite the varied forms of authority associated with particular kinds of participation structures (such as group roles), there is no research focused on examining the conditions under which leader roles, which enable the leader to issue directives to peers, support or discourage equitable group work. The role of group leader has often been included in research on group work in ways that assume its benefit. Though such participation structures may afford students positions of authority, the role of leader is not only up to the student assigned that role but also depends on how the other group members take up the leader's directives rather than reject or modify such positions (Langer-Osuna, 2011). Here, each student was offered opportunities to take on leader-related roles that contributed to the management of the problem-solving process of their group.

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# Theorizing Learning in the Context of Social Movements

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**Abstract:** Studying learning in social movements is important for Learning Sciences researchers because it can help us (a) understand how learning occurs at and affects multiple levels of historical, cultural, and social activities and (b) how marginalized communities participate in framing problems and their solutions. The four papers in this symposium present empirical research from diverse international movements, including the local foods movement in Colorado, youth organizing for educational equity in South Africa, school food reform in Spain, and nationalism in Libya and Italy. Each of the papers address how local actors exercise agency in relation to complex, dynamic, contested social movements. Implications discuss *how* social movements collectively organize just social futures and the role that learning scientists can play in lending analytic precision to these processes.

## General Introduction

Learning scientists, particularly those working from situated or sociocultural perspectives, have argued for several decades that research on learning must attend to the ways that learning environments are mediated by culture and history. Classic learning sciences texts, including Bransford, Brown, and Cocking (1999), and Sawyer (2006), include sections devoted to explaining how cultural practices outside of school influence learners' experiences in school and how classroom and school contexts shape opportunities to learn.

We worry, however, that research on learning too often foregrounds dynamic learning trajectories against a presumed stable or static context. We take the position, consistent with social practice theory, that just as individual learners may be changing and growing, so too are cultural practices. Such practices are challenging to study, however, because the pace at which they change is typically much slower than microgenetic or even ontogenetic change (Rogoff, 2003; Wortham, 2005). Despite the challenge, we need to figure out ways to study learning as a form of cultural or social organizing aimed at developing new social futures (Penuel & O'Connor, 2010). Social movements provide a particularly helpful example of this.

Social movements are valuable sites for investigating processes of learning and becoming because as part of them, groups of people are explicitly attempting to change and challenge the structures that shape their actions and those of their communities (Holland, Fox, & Daro, 2008). Studying social movements could be advantageous for Learning Sciences researchers because it can help us understand (a) how learning occurs at and affects multiple levels of historical, cultural, and social activities and (b) the greater inclusion of marginalized communities in framing problems and their solutions.

We frame our research within a social practices perspective that argues for the importance of studying the organizing processes involved in learning and social change (Lave & Wenger, 1991; Holland, Lachicotte, Skinner, & Cain, 1998). A key assumption of this perspective is that researchers of learning should attend to the active and often contentious work of organizing people, things, and ideas to create access to valued social futures (Hall, Wieckert, & Wright, 2010; Nespor, 2004). Building on this perspective, Penuel and O'Connor (2010) have argued that scholars interested in learning should focus on activist projects, as these involve not only the purposeful organizing of new forms of practice and knowledge, but also of linkages between prior forms of practice and knowledge across settings. The "historically new forms of activity" that emerge from these projects often challenge those developed within and rewarded by dominant social groups, and expand opportunities for action, especially among non-dominant communities (Engeström, 1987; Gutierrez, 2008).

In this symposium, we bring together four research studies that examine the relationship between dynamic societal change and individual learning "with the goal of supporting new forms of learning":

- Jurow, Teeters, Shea, and Severance examine learning and social change in the local food justice movement in the western United States.

- Torralba and Guidalli study examines the eating experiences of children in Spanish schools as forms of activism against a reductionist school food reform.
- Kirshner, Dutilly, and Griffin-EL investigate how an educational equity movement in South Africa coordinates local youth participation with national strategy.
- El Taraboushi studies the structures that facilitate and impede the development of citizenship in the context of nation building in Libya.

In an increasingly interconnected world, our studies of learning and becoming must account for local-global interactions. Each project highlights the agency of people as they are mobilized by and create new forms of practice through social movements. Each site under study has a unique history, patterns of immigration, geographic organization, and economic development, which is critical to how each of the researchers conducted their analyses. The purpose of our symposium is to draw out common issues shaping learning and becoming as people engage in re-assembling scales of practice and their relations to each other. In his role as discussant, Rogers Hall (Vanderbilt University), will use his expertise in studying learning across multiple scales in the context of shifting cultural practices at work, in schools, and communities to provide critical commentary and raise implications for the learning sciences. Some of the questions that we hope our cross-context and cross-methodological studies raise include:

- In communities facing social upheaval and social injustices, how do people organize new ways of participating in civic society?
- What methodological tools and insights could learning scientists productively employ for examining learning across local and global contexts?
- What are some of the tensions for researchers studying activist projects?

## **Expansive Learning in the Urban Food Justice Movement**

A. Susan Jurow, Leah Teeters, Molly Shea, and Samuel Severance

This paper examines social processes of learning in the local food justice movement. Our project is situated within collective efforts of private, non-profit, and governmental organizations to transform how food is produced, distributed, and consumed in the western United States. Many of these organizations focus on increasing food access for the most vulnerable populations in the state where we conducted the research; some center on food itself as a core component of promoting community health, while others use food as a means of working for social justice. As we have found through our ethnographic and participatory research, this movement has provided a means for communities to resist, transform, and learn in the “tight circumstances” in which they live (McDermott, 2010).

Our findings come from a two-year, ongoing study of community organizing led by a non-profit organization working closely with residents in a largely Mexican immigrant community. The neighborhood has been designated by the U.S. Department of Agriculture as a *food desert* because there are a large number of people living in poverty with limited access to healthy foods (USDA, 2012). The non-profit has the dual aim of empowering residents and improving food access. It uses an approach that relies on *promotoras*, i.e., residents hired to facilitate links between the non-profit and the community. The promotora model originated as a Latin American public health strategy; it was developed to help institutions like hospitals capitalize on the shared cultural practices and language backgrounds between promotoras and residents to facilitate desired health goals (Elder, Ayala, Parra-Medina & Talavera, 2009). In the focal neighborhood, promotoras act as community connectors between the non-profit and the community. A central part of the promotoras’ work involves teaching residents to grow their own backyard gardens, which can provide them with fresh, organically grown food.

The backyard garden program has created new connections between people, practices, and values and has expanded possibilities for learning and action (Engeström & Sannino, 2010). Our first finding reveals that through their compassionate and sustained engagement with community members, promotoras have developed a critical perspective on the needs of residents, the inequities facing their community, and a sense of responsibility as emerging civic leaders. Our second finding documents how the promotoras’ changing sense of who they are becoming has affected their actions in the community. Their initial aim of growing gardens has grown to include a desire to challenge inequitable relations of power through reorganizing residents’ access to social, educational, and economic resources. In collaboration with the non-profit leadership and residents, promotoras are now deeply engaged in developing a community-owned food cooperative and a commercial and educational kitchen.

Our study underscores the need to develop ways of theorizing learning as it is situated in intricately tangled networks of practice. Promotora learning, for example, took shape in relation to historical patterns of immigration, the uneven development of educational and health resources in the city, and changing conceptions of food production and community. To create greater equity within and across these networks of practice, we need to examine efforts that aim not only to reveal their tensions, but also strive to transform them (Avis, 2007). Radical social movements like the local food justice movement provide a powerful avenue for studying social change and its implications for learning, becoming, and organizing a just and sustainable world.

# **Examining Children's School Eating Practices as Processes of Learning to Envision Alternative Forms of Social Participation: Implications for School Food Reform**

José Antonio Torralba and Barbara Guidalli

How do school children's and youth's eating practices and understandings of food constitute a form of activism that disrupts existing school food reforms and seeks to re-store social and cultural aspects of food and eating? Answering this question requires us to focus on the active participation of children in a process or practice that has attracted little or no attention from the educational research community (Weaver-Hightower, 2011) and in which children have been conceptualized as passive recipients of adults' designs. It also encourages an examination of learning, development, and becoming within complex social-cultural and politicized contexts (Poppendieck, 2010), where issues of becoming intersect with social and personal activism. Within the reductionist context of school food reform in Spain, often recognized as 'nutritionism' (Scrinis, 2002; Pollan, 2008), we document students' statements and actions that disrupt underlying assumptions of those reforms (namely understanding and producing food and eating experiences in terms of nutrient intakes) and seek to re-store key aspects of food and eating (e.g., sociability, pleasure, traditional meals) aligned with children's identities as cultural and social eaters (Haden, 2006).

In this paper, we show how children in Spanish schools envision themselves as school eaters and through that process offer alternative visions of the school foodscape and their positioning within it. We understand this process as a form of activism because it seeks to change, or at least create the underlying conditions for changing, the organizational structures and eating experiences of students in schools.

We employ the notion of *foodscape* (Mikkelsen, 2011; Johansson et al, 2009) to re-store analytically the social, economic, political and cultural elements to a practice - *eating* - and a setting - *the school lunchroom* - that have been examined in very restrictive manners (cognitively and socially). Working within this new perspective, we examine issues of learning to become a particular practitioner (Lave & Wenger, 1991) and elaborate a construct, "eater-in-context," to ground our emerging understanding of learning and becoming within the context of eating in schools. We think children's active roles in learning and becoming are also attempts to modify or change the context in which one is forging an identity, namely providing alternative images of the school foodscape. We treat documented eating practices and preferences as a form of activism because they are deployed and offered by students to modify or critique the existing conditions and to position themselves as a different type of eaters than that expected by the institution of school. Eating in a way that disrupts traditional Spanish meals or not eating certain foods because of their appearance, lack of ingredients, preparation, and/or presentation are all ways to become an activist and offer forms of resistance to and proposals for different eating experiences in the school foodscape. We examine these processes as a way to produce questions of learning and becoming in socioculturally and politically complex settings at the individual and collective levels. We employ two vignettes to do this.

At the individual level, we show how Iñigo, a second grader, employed the geography of the school lunchroom to suggest and obtain changes with whom he participated during eating. He joined a particular group and once there, learned to participate in the eating practices of that group to craft an identity as a third grade eater. His activism resides in the fact that he demonstrated how the organizational structures of the school lunchroom could be employed to advance his aims of becoming part of a practice (a third grade eater). At the collective level, we examined statements produced by children from different grade levels and schools in reference to school food and eating experiences. We use these statements and their contexts as evidence or representations of these children's envisioned identities as school eaters. We treat these visions as part of a child *activist* positioning that has been systematically ignored but that continues to impact and to some degree guide the initiatives of school food reform (e.g., school food waste, preferences, conditions, etc.). The changes that emerged out of this activism included a call for greater autonomy in the eating experiences of students at school, a call for more equitable forms of eating, and a call for meals that are prepared and offered in ways that better aligned with their social and cultural perceptions of food and eating. Based on these analyses, we conceptualize becoming a school eater as a way to:

- appropriate ways of eating that are deeply context-bound (eater-in-context), and thus unique to the school foodscape;
- compare elements of different foodscapes to articulate (sometimes in the form of criticism) an image of one's eating experiences inside the school foodscape; and,
- develop a personal notion of eating as a collective social activity.

The school lunchroom is a highly contentious and politicized place (Poppendieck, 2010), where notions of health, economics, childhood, parenthood, and education compete to craft the eating experiences of children. Examining learning and becoming in such a complex system (foodscape) from the perspective of the eater may represent a productive opportunity for re-examining the capacity and limitations of the bounded system

conceptualized by researchers from the social cultural historical activity theory perspective (Engeström, 1987). Because we conceptualize learning and development in the school foodscape as a form of activism (i.e., a way for children to engage in actual or prospective change), we are proposing that processes of learning within this context are interesting in that they may emerge in constant tension with a parallel activity system- that of the institution. How children in such a tension-dense context craft learning and identity is a question worth examining.

## **Every Generation Has Its Struggle**

Ben Kirshner, Erik Dutilly, and Nosakhene Griffin-EL

How do ordinary young people work together to change institutions or policies that affect their lives? Complex systems are notoriously hard to alter, especially for youth who lack voting rights and financial resources. Furthermore, the local scale at which youth may experience problems – such as lack of computers in their schools – is not the scale from which the problem originated (Kurtz, 2003). Current theories of civic learning are limited because they do not conceptualize the problem of agency at the proper scale. They tend to privilege classrooms rather than networks, discrete action projects rather than movements. In this sense they do not provide theoretical clarity to describe the kinds of coordination challenges facing organizations that aim to facilitate youth participation in social movements.

We address this shortcoming by drawing on work by Nespor (2008) and Zuckerman (2013) to conceptualize and study the social production of political agency in one youth organization, called here Learner Rights, located in South Africa. We examine how young people between the ages of 15 and 24 learn to participate in a complex, nation-wide social movement for educational equity. Claims are based on data collected during 12 months of ethnographic and archival research, including field notes from meetings with youth, interviews with youth leaders, organization documents, newspapers, and historical analyses.

Our findings focus on the ways that Learner Rights (LR) 1) situates its work in a historical narrative and 2) coordinates local scales of meaning with national scales of regulation.

With regard to historical narratives, today's critics of the African National Congress, South Africa's governing party, confront a dilemma. Criticizing the ANC, which is in power because of its recognized "struggle credentials," risks being painted as not in solidarity with the South African liberation project. Furthermore, young people today, known as the the born-free generation, have only known the post-apartheid state.

In this context, LR has developed a narrative that claims its legitimacy by linking the revolutionary struggles of the apartheid years to the present day movement. Several examples from our fieldwork demonstrate this effort to situate the work in a broader historical narrative, best exemplified in LR's slogan, "Every generation has its struggle." The creation and singing of songs are another example of linkages to "the struggle," because of the role of "struggle songs" in the anti-apartheid movement. Group singing at LR events is common; the songs include ones that attach new lyrics about contemporary issues to melodies from older struggle songs.

With regard to our second finding, people tend to experience injustices at a local level (scales of meaning); but often the solution to these injustices can only be found at a more geographically diffuse national set of policies (scales of regulation) (Kurtz, 2003). For example, the "scale of meaning" for most ELRE members is located in their school or township. But learners attending township schools can only get so far in targeting their school principal to address brick and mortar issues.

LR manages this scale dilemma by developing, coordinating, and exercising power at three different scales, all in the service of the same campaign. The first scale is local and seeks to build power in numbers by mobilizing students and their families around issues that affect them directly, such as poor sanitation in their schools. The second scale is legal: EE has an affiliated "law centre" that researches statutes and files legal briefs. The third scale is devoted to media communications and messaging.

In a time when ordinary people may feel that government is unaccountable or that the avenues for social change are too opaque, social movement organizations fill an important need. This paper shows how LR's effort to foster youth participation in radical social change involves coordination across various scales of history, meaning, and regulation.

## **Statehood in Purgatory: Regionalism, Nationhood and State-Building in Italy and Libya**

Sherine El Taraboushi

Studies of civic development are almost uniformly set against a context of national stability or assumed statehood. Ongoing mobilization in North Africa and Europe, however, underscores the need for historically grounded theories of citizenship that account for the messy, dynamic, and conflict filled process of nation and

state building. This paper offers possible direction for such efforts by engaging in a comparative analysis of the struggle of nation and state building in two neighboring countries—Italy and Libya.

In his book, *A History of Modern Libya*, Vandewalle (2006) highlights an important point in Libya's relation to its colonizer; when Italy invaded Libya in 1911, it had only been “unified” for fifty years (24). Italy could not provide a model of statehood to which the Libyan people might have aspired to after liberation; it did not have much experience in state building itself so it had little to contribute to an already existing non-state. Moreover, Italy had suffered from extreme regionalism that compromised the development of a solid imaginary of the nation and placed state-building structures in a continuous flux; historical differences between the Northern regions and the Southern ones produced very complex and diversified understanding of nationhood. In nineteenth century Italy, Royal Prime Minister Massimo D'Azeglio of Sardinia-Piedmont described how the unification had made “Italy but not Italians” (p. 128, Amoretti, 2002). The nation as imagined was fragmented so it could not provide a model of that to the Libyan population, nor were the Libyans given a chance to organically develop structures for both statehood from within; continuous political and economic instabilities along with the absence of an indigenous capacity to produce those structures thwarted their development.

The process of “learning” and developing tools of state building was impeded, an imaginary of the nation was confused, and so the process of “becoming” a coherent nation and a consolidated state was not made possible. Both Italy and Libya struggle today because of incomplete state building and nation building processes. There is a need to develop frameworks of understanding of the transition from a non-state to statehood in terms of its implications for civic participation as well as building institutions that contribute to or thwart statehood.

The role of institutions in state building and the role of cultural constructs in nationalism are central. The core question is if it is possible to establish a state with a confused sense of nationhood. Which comes first? What kind of lessons learned can we obtain from other countries that can help inform our understanding of the crossroads between both? I propose to take state and nation building to their points of departure and explore in light of those examples how the path from a non-state to statehood was thwarted or made possible. Critical to my historical analysis is the role of institutions, formal and informal, in allowing or preventing that transition across the trajectory from unification or liberation to the present. Historical institutionalism will be used as an approach in the analysis with a revisiting of North's (2009) thesis on transitioning from one social order to another and his concept of an Open Access order. Special emphasis will be placed on the role of civil society and citizen mobilization in state building and establishing understandings of nationhood. The approach and methods that inform this research are qualitative and combine both history and social anthropology. Data sources include archives in Italy at the University of Bologna and exploring recordings of oral history at the Center for Libyan Studies in Tripoli. In depth interviews and focus group discussions will also be conducted with civil society leaders, activists and government officials to inform my analyses.

## Conclusion

The focus of this symposium is on understanding the nature of learning in social movements. To date, social movements have received relatively little attention from learning sciences researchers. We argue, however, that they provide a powerful perspective for examining transformative learning and the emergence of new cultural practices in shifting sociohistorical contexts. This holds great potential for learning sciences research, particularly efforts to design for greater equity for historically marginalized communities. Through comparison of four investigations into social movements situated in different parts of the world, we aim to stimulate discussion of the possibilities of social movement research for the learning sciences and educational practice.

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# Concept Formation in Activity

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**Abstract:** This symposium introduces the study of formation of concepts in collective activities (concept formation “in the wild”) as a new research field in learning sciences. Using meditational and activity-oriented theoretical frameworks, the contributors analyze concept formation in diverse activities, asking: What are the key characteristics and mechanisms of emergence of functional concepts embedded in activities and what analytical dimensions might be fruitful for the investigation and facilitation of the formation of such concepts? What are the potentials and limitations of different mediational means and multimodal instrumentalities in the formation and development of functional concepts? How are volition and future-oriented agency intertwined with the formation of functional concepts?

## Overview of Symposium

Concept formation and conceptual change are central topics in studies of human learning. However, these topics are studied predominantly in laboratory and classroom contexts in which the focus is on individual learners and the concepts to be acquired are neutral, well known and defined by the researchers or instructors ahead of time. The formation of functional concepts (Greeno, 2012) in work and other collaborative activities “in the wild” has only recently been identified as a field of research (see the special issue of *Mind, Culture, and Activity*; 3/2012). Embedded in activities, concepts need to be understood as complex, emergent, contested and volitionally charged collective constructs that have serious practical consequences for communities (Engeström & Sannino, 2012). This is a new challenge to the learning sciences.

The objectives of the symposium are to take a step forward in the development of the newly formulated research field characterized as concept formation in the wild, to open up analyses of future-oriented volition as an important aspect of concept formation, and to bring together for comparison and exchange empirical analyses of different cultural contexts of concept formation and volition embedded in human activities.

Cultural-historical and activity-oriented theories (Vygotsky, 1997; Davydov, 1990; Hutchins, 2005; Nersessian, 2012) regard concept formation as crucially dependent on the construction and use of mediating means, specified as material anchors, models, or signs. Traditionally language has been seen as the dominant mediator and modality of concepts. However, there is increasing evidence that functional concepts take shape and function by means of multiple interacting modalities, ranging from the body to physical artifacts, pictures and graphic representations, symbols and various sign systems. The mediational means and multimodal instrumentalities involved in the formation and development of functional concepts are a central issue addressed by the contributors to this symposium.

Vygotsky (1997) built an explicit connection between concept formation and volition with his principle of double stimulation. In collaborative activities the formation of future-oriented concepts and volitional action to construct the future in practice go hand in hand. We may speak of future-oriented perspectival concepts or possibility concepts (Engeström & al., 2005). These qualities point toward an important, yet practically unexplored connection between concept formation and volition. Volition may be understood as the capacity to form and implement intentions that go beyond and transform the accepted routines and given conditions of the activity in which the subjects are involved. In the symposium, concept formation is discussed as a volitional and agentic process. This is a novel perspective on concept formation that requires ambitious theoretical, methodological and empirical work.

The papers of the symposium will address the following major questions:

- What are the key characteristics and mechanisms of emergence of functional concepts embedded in activities and what analytical dimensions might be fruitful for the investigation and facilitation of the formation of such concepts?
- What are the potentials and limitations of different mediational means and multimodal instrumentalities in the formation and development of functional concepts?

- How are volition and future-oriented agency intertwined with the formation of functional concepts?

The four papers focus on concept formation and learning in different activities and cultural settings, ranging from home care for the elderly in Finland (Engeström) to an internship of future elementary school teachers in Italy (Sannino), public schools in Moscow, Russia (Lapshin, Safronova and Virkkunen), and greenhouse vegetable farms in Finland (Vänninen and Pereira Querol). The discussant will be Professor Rogers Hall (Vanderbilt University).

## What are Functional Concepts?

Yrjö Engeström, Center for Research on Activity, Development and Learning (CRADLE), University of Helsinki

Functional concepts embedded in collective activities are typically polyvalent, contested and contradictory. They carry ethical and ideological challenges and visions. They are often “loose” (Löwy, 1992) and generate surprising manifestations. They cannot be easily defined and put to rest as categories in a dictionary. Yet we need functional concepts as tools, which makes it necessary that we try to fix and stabilize them, at least temporarily. Formal-logical notions of a concept are not sufficient for the understanding of functional concepts (Greeno, 2012).

This paper will examine five key dimensions of functional concepts, namely (1) the dimension of empirical vs. theoretical contents of concepts, (2) the dimension of verbal vs. multi-modal mediation of concepts, (3) the dimension vertical vs. horizontal movement and interplay of concepts, (4) the dimension of stabilized vs. fluid or loose concepts, and (5) the dimension of adaptive vs. transformative agency. Two examples of functional concepts with which we are currently working in our research group will be analyzed through the lenses of the five dimensions. These are the concept of *integrated pest management* or *IPM* (Kogan, 1998) as it is shaped and implemented among greenhouse vegetable growers in western Finland, and the concept of *sustainable mobility* as it is constructed and implemented among the workers and clients of home care for the elderly in Helsinki, Finland (Engeström, Nummijoki & Sannino, 2012).

For Vygotsky (1987), the key difference between what he called everyday and scientific concepts was that the former are learned in personal casual experience whereas the latter are acquired by means of instruction in school. Davydov (1990) points out that this distinction tells nothing about the *contents* of the two types of concepts. The second key difference between everyday and scientific concepts according to Vygotsky is that the latter form hierarchical systems while the former are without a system. Davydov points out that also empirical concepts commonly appear in systems, such as genus-type relationships, elaborate classifications and pyramid-like hierarchies. In other words, the existence of a system or hierarchy of concepts in no way guarantees that it is a theoretical or scientific concept. For Davydov the essential point is that with empirical concepts you perform actions of comparison, identification, naming, and classification. Empirical concepts are definitions and categorizations that aim at fixing and freezing the reality, creating closed compartments which can be filled or matched with appropriate examples. Theoretical or dialectical concepts are procedures of ascending from the abstract to the concrete in a given domain, requiring actions of historicizing, transforming and experimenting, modeling (constructing a germ cell abstraction), examining or testing the model, and deriving new expanded implications and applications from the germ cell (rising to the concrete). Theoretical concepts are open-ended, they generate constantly new possibilities and applications. Both the concept of *integrated pest management* and the concept of *sustainable mobility* can be used either as an empirical categorization device or as a theoretical device for ascending from the abstract to the concrete. The paper will demonstrate how these alternatives, and their mixtures, are displayed in the history and current life of these two concepts.

Vygotsky emphasized the verbal, language-bound character of concepts. On the other hand, researchers such as Poddyakov (1977; 2011) have shown that already preschool children are capable of key actions of theoretical thinking, namely experimentation and modeling, using material artifacts and visual images. Our own work (Engeström, Nummijoki & Sannino, 2012) points toward the great potential of physical movement and bodily sensation in the formation of theoretical functional concepts. The paper will analyze how each of the two concepts discussed here appears in different guises, as verbal definitions and instructions, as graphic models and pictorial representations, and as bodily actions and sensations, and how the movement and blending between the modalities may be obstructed or facilitated in various ways.

The vertical movement of concepts was powerfully discussed by Vygotsky and Davydov. The horizontal movement may be understood as comparison, confrontation and blending between different perspectives and definitions of a concept (Engeström & al., 2005). This polyvalence is present not only in newly emerging concepts such as *sustainable mobility* but also in a concept with a long history and official authority such as *integrated pest management*.

Stabilization of functional concepts typically happens by means of political, economic and legal authorization and investment. Functional concepts serve as future-oriented visions that engender transformative

agency. But they also serve as mechanisms of adaptation, calling for adherence to received wisdom and gradually becoming self-evident components of hegemonic consciousness. Thus, as Löwy (1992) shows, certain looseness in key concepts may be necessary for the development of our understanding of complex phenomena. Along with stabilization, we may observe, perhaps also facilitate, processes of destabilization of functional concepts.

## **Anchoring Backward and Anchoring Forward: Conceptualization and the Emergence of Agentive Action**

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In situations of uncertainty or cognitive incongruity human beings usually turn to conceptual and material anchors to support sense making and engage in meaningful actions. Available literature on anchoring primarily focuses on what may be characterized as backward anchoring, that is, well-stabilized representational components in the conceptualization processes involved in these situations. On the other hand, literature on sense- and meaning making does not systematically identify actions involved in this conceptualization processes. With the help of empirical analysis in laboratory setting, the analysis presented here aims at opening up a way toward a notion of forward anchoring which involves both conceptualization and agentive action.

Anchoring backward relies on background knowledge and relatively stable representations utilized for explaining problem situations and for acting in such situations. Conceptualizations of anchoring proposed by Tversky and Kahneman (1974), Moscovici (1984) and Marková (2000) are examples of this type of anchoring: reliance on starting points yielding to biased estimates (Tversky & Kahneman, 1974) and categorization of new or unfamiliar ideas under familiar concepts and their transformation into cultural beliefs (Moscovici, 1984; Marková, 2000).

Anchoring forward is stepping into the unknown by building supporting anchors partly similar to material anchors depicted by Hutchins (2005). Forward anchoring involves representations not yet consolidated, emerging through personal sense and social interactions. These anchors are instrumental in the elaboration of new meaning, which may be stabilized to the point of supporting actions. In this paper, the notion of anchoring forward is elaborated on the basis of Vygotsky's (1987) principle of double stimulation, according to which one turns to external means for support to produce a new meaning and to be able to act.

Studies using the idea of double stimulation primarily examine concept formation without addressing how emerging concepts are related to agency. This was, however, a central concern for Vygotsky and the continuing relevance of Vygotsky's legacy largely resides in the relation between concept formation and volitional action. Vygotsky (1987; 1997; 1998) used the experiment of "meaningless situation" as a paradigmatic example of double stimulation. A subject escorted to a room is told that the experiment will start soon, but the experimenter does not return. This design allows tracing how the participants start forming a concept of the situation and how they engage (or fail to engage) in agentive actions. Videotaped, annotated and transcribed experiments with 25 individuals and 30 groups, based on Vygotsky's description, are analyzed in this paper, together with participants' stimulated-recall interviews, also recorded and transcribed.

The other set of empirical data used in the paper concerns a formative intervention to develop the internship of future elementary school teachers in Italy. 13 third-year university internship students were involved in the study. One or two first- and fourth-grade pupils were assigned to each internship student who assisted them in accomplishing learning tasks. As none of the internship students had prior teaching experience, the interactions with the pupils proved to be at times challenging situations which required conceptualization efforts and agentive actions. The data in which the students report how they dealt with these challenging situations include 108 ethnographic fieldnotes by the internship students, transcriptions of 28 interviews and 10 meetings with the internship students.

The two empirical sets of data are analyzed by focusing on both verbal and physical aspects of interaction to investigate how double stimulation is simultaneously a mechanism of conceptualization and agency. The analyses reveal both backward anchoring-based conceptualization actions and forward anchoring-based conceptualization actions. The latter are in turn further differentiated into search actions, taking-over actions, and breaking-out actions. The analyses lead to the formulation of a hypothesis of the interrelatedness of conceptualization efforts and the emergence of transformative agency.

## **School Change as Collective Concept Formation**

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The problems typically encountered in attempts to profoundly renew school education are aptly crystallized in the conclusion of an analysis of a school reform program conducted by Hubbard, Mehan and Stein (2006): "(...)

*a reform that began as conceptually driven was proceduralized; an approach to learning that began as student-centered became teacher-centered; a framework with many openings for the application of professional judgment became understood as scripted.*" In our paper we argue that a predefined concept easily turns into a rule for the practitioners rather than into an intellectual tool for creatively meeting the challenges of their joint activity. The practitioners need to be involved in the process of forming the new concept for it to become a motive and instrument of their transformation efforts. The formation of such a concept requires that practitioners take jointly epistemic actions to reveal the change-demanding inner contradictions within their activity system and to find and implement a way to re-mediate them.

The Change Laboratory is a formative intervention method that is designed for helping practitioners to accomplish this in collaboration with researcher-interventionists. The Change Laboratory aims at creating a theoretical abstraction of the new form of activity and ascending from it to the concrete new activity system (Engeström, 2007; Virkkunen & Tenhunen, 2010; Virkkunen, Newnham, N'leya, & Engeström, 2012). This process also builds the practitioners' transformative agency. In our paper, we will analyze such collective concept formation processes in two Russian schools.

### **The School Integration Case**

Education in the Russian Federation is currently in the process of being modernized. A new system of educational objectives is implemented that highlight the development of students' general learning abilities. At the same time, separate educational institutions are merged to form Educational Incorporations in order to secure equal educational opportunity and to raise the quality of education. In the first case we analyze in our paper, a senior high school (Gymnasium), a public school and two kindergartens are being merged. Our analysis of this transformation focuses on how the ideas behind the externally given new rules can be turned into new conceptual and practical tools for the practitioners to master the new challenges. That is only possible when they construct a future-oriented concept of a shared object of the educational activity of the professionals of the new institution. In a Change Laboratory process conducted in 2013, 18 administrators and teachers from the four previously separate institutions analyzed the development of their educational activities. The analysis showed that inner contradictions had evolved within each institution's activity that the fusion aggravated while also providing new potential for resolving the contradictions, highlighting the need to find a concept of a jointly produced "product".

In the Change Laboratory discussions, the idea of *individualized instruction* emerged as a possible core of the new concept, based on the senior high school's existing practice of constructing individualized study plans as well as on the other institutions' experiences of individualizing instruction. We will examine the concept created in the Change Laboratory against the historical variations and phases of development of this concept (e.g., Gibbons, 1970; Rothrock, 1982; Hiemstra & Sisco, 1990). We will analyze the steps of ascending to a new concrete system of the joint activity of the merged institutions as stepwise resolution of manifestations of the *contradiction between the individual and the common* in the education on different levels of the new institution's activity.

### **The Case of Redefining the School's Educational Activity**

The "School of Self-Determination" at Moscow's periphery was created to educate self-confident, cultured and active persons and over the past three decades it developed a community of kindred spirits around itself. Lately, however, its pedagogical efficiency as well its reputation in the local community have declined. The ongoing school reform in the country forced the school to begin to redefine its activity. This effort was supported by a Change Laboratory intervention from October 2012 to March 2013, in which a representative group of 24 teachers and managers took part. Interviews and videos of work situations were used as stimuli and material to discuss and analyze the current situation. Origins and systemic causes of the problems were traced in the Change Laboratory by analyzing the historical development of the activity. The analysis revealed contradictory needs and pressures within all elements of the activity that the school reform further aggravated. The reform requires the school to focus on academic results. It sharpens the contradiction between two ideas of the school, understood as "a school for all" and "a school for kindred spirits". The core of this contradiction was modeled in the Change Laboratory through two orthogonal dimensions of developmental objectives: "openness of the school" and "commonality of values" within the school community. The challenge was defined as a need to integrate these objectives. The participants sought to realize this with a new formulation of the object and concept of their educational activity: "Each pupil is potentially able and individually gifted to be a subject of his or her own educational trajectory; to learn from his or her own strengths and weaknesses; and to choose his or her own way of development". Each element of the activity was redefined on the basis of this concept. Task force groups were formed to work on concrete tasks of implementation. The headmaster and four teacher leaders coordinated this work. Follow-up data shows that the practitioners have actually managed to concretize the abstract germ cell of the concept.

## **Observations**

In both these Change Laboratory processes, a dialectical process evolved in which the new external demands and pressures, the practitioners' own experiences and concepts, the history of the institutions, and their future perspectives were brought into a creative dialogue. The practitioners reviewed the history of their activity from the point of view of their current challenges and at the same time approached the latter through their historical experience and the resources inherent in it. Instead of receiving the school reform as an external rule the practitioners integrated it in their analyses of their activity as an change in conditions that aggravated the inner contradictions in the activities and provided new resources for resolving them. Abstracting and modeling the central inner contradictions in the activities enabled the practitioners to make thought experiments and, through them, to cross the boundaries of current classifications and institutions. In both cases a new concept evolved as a new vision and motive of the activity and as a principle the practitioners' applied in resolving the contradictions of their activity both in thinking and in practice, thus objectifying the new concept through reconfiguration the organization and the daily practices of the schools' educational activity.

## **The Role of Models and Modeling in Collective Concept Formation: Transforming Pest Management in Finnish Horticulture**

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Models are understood as special kinds of mediating artifacts that play a crucial role in helping us to learn about theories and the world (Morgan & Morrison, 1999). Studies of the role of models in scientific practice provide some knowledge about the relationship between theories and reality, but they do not say much about how models are used in the process of transforming activities (for important work in this direction, see Nersessian, 2012). In this paper, the case of greenhouse vegetable production in Ostrobothnia, Finland, is analyzed as case in which models are needed in the creation and implementation of a concept that guides the transformation of an activity. The learning challenge of the producers in this context is to construct an integrated management of a systemic whitefly problem. The individual producers need to overcome their competitive separation and construct a shared pest management system at the level of the whole village. The study was conducted as a Change Laboratory intervention (Virkkunen & Newnham, 2013) designed to facilitate collective pest management among the producers.

In the six Change Laboratory sessions the participants constructed and used a series of graphic models do depict, analyze and transform their problematic situation. By tracing the generation, application and modification of these models, we show how the object and concept of whitefly management was reconstructed during the collective learning process and how different forms of transformative agency emerged in the process. Using the framework of expansive learning (Engeström, 1987), we analyze in which phases of the expansive learning cycle the models were created, what specific purposes they served, what modalities of representation were involved (e.g., how the graphic models interacted with bodily gestures and verbal discourse), and which types of expressions of transformative agency (resisting, criticizing, explicating, envisioning, committing, and taking actions) they were connected to.

We identified three models that contributed to the expansive re-conceptualization of the activity and reconstruction of its object. The most important model served as a springboard for expanding the participants' understanding of the whitefly problem and consequently expanding the solution. The model represented the interplay of the outdoor and indoor parts of the whitefly problem and its contributing factors. It took the general form of a vicious circle, a sequence of reciprocal cause and effect in which two or more elements intensify and aggravate each other, leading inexorably to a worsening of the situation until an external factor breaks it. The model was developed in several stages during the questioning and analyzing phases of the process. The initial version was produced by growers with the help of the facilitators. Thereafter its development was continued collaboratively by growers, advisors, facilitators and the tutor of the process. It was notable that the initial versions of the model did not include the leverage component of the ensuing new model of activity: improving communication to share information between growers. The modeling process helped the participants go beyond mere bio-ecological and technical aspects of the problem, opening up the social system and its contribution to the whitefly problem and directing attention to those parts of the system that could be used as leverage point to break the vicious circle. The model helped growers to form the new object of whitefly control that is more realistic for a community of interdependent producers: not eradicating but keeping whitefly levels continuously low through collaboration. The model was referred to several times both during and between the sessions. Thus it guided thinking, triggered participants' agentic actions, and guided them in forming hypotheses on how to deal with the problem.

Based on the problem model and the associated solution components, in the solution design and testing phases the interventionists designed a second model representing a solution to the problem. The core of the model stemmed from a realization obtained when constructing the system-specific vicious circle: that a new division of labor was needed between firms for producing information that would help them improve pest

management collectively. The solution includes a standardized monitoring method of whitefly densities in the farms, a boundary object (Akkerman and Bakker, 2011) in the form of a database for storing monitoring and pest management results, and a learning club involving growers, advisors and researchers for collective analysis and discussion of the data and related pest management approaches. The solution model guided the planning of practical trials of the monitoring tool of whiteflies as well as the planning of rules for the learning club. Additionally, it proved very useful in the last session of the Change Laboratory when introducing the new concept to the growers of the neighboring village in an attempt to geographically expand the new activity.

The third model was produced and used during the testing and implementation phase to help in deciding about the format of the learning club, the two options being a webpage or face-to-face meetings. The interventionists produced a prototype webpage to exemplify how and what kind of information could be made available through the web. Prototyping enables designers and users to test new ideas through thinking-by-doing (Hartmann & al., 2006). The prototype eventually helped the growers decide in favor of face-to-face meetings that suited their learning needs best for the time being.

A preliminary analysis shows that growers first tried to reach a solution by applying the prevailing approach to solving problems; this often involves fixed roles and individual responsibilities. During the intervention, limits of the current concept and practice were recognized. The construction and use of the system-specific model of the problem were important in triggering the agentive actions of criticizing and explicating possibilities. The second and third models were important in triggering and supporting envisioning.

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# Cyberinfrastructure for Design-Based Research: Toward a Community of Practice for Learning Scientists

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**Abstract:** This symposium is part of an NSF project to help The Learning Sciences community collaboratively envision a cyberinfrastructure for design-based research (DBR). Like numerous others before us, we argue that the educational research community would be well served by a mutually created cyberinfrastructure that would encourage and support engagement by multiple design-based researchers in sharing knowledge and working toward answers to important theory-driven research questions, moving our field toward a “bigger science” approach. The vision is one in which junior and senior scholars set collaborative research agendas and establish common protocols and systems to support systematic collaborative archiving, sharing and analysis of multi-modal data. This symposium offers critique, reflection, and concrete proposals for design, helping demonstrate the possibility of implementing this idea and moving it toward becoming reality.

## Chair's Introduction

Sharon J. Derry

## The Problem

Design-based research (DBR) is a mixed methods approach that involves the iterative and systematic design, development, and study of theoretically guided educational innovations in their implementation contexts (Barab & Squire, 2004; Collins, Joseph & Bielaczyc, 2004; The Design-Based Research Collective, 2003). Although DBR is in early stages of development as a methodology and paradigm, its popularity among researchers, funding agencies, and journals is growing and spawning lively academic debates (e.g., Anderson & Shattuck, 2012; e.g., Dede, 2004; McKenney & Reeves, 2013). In a penetrating commentary on the special issues devoted to DBR in *Educational Researcher* (2003) and *Journal of Learning Sciences* (2004), Dede (2004) worried that discussions had pushed the boundaries of DBR too far, rendering a sort of “Swiss Army Knife” for scholars trying to find a tool for too many purposes. He encouraged instead a bounded conceptualization (e.g., Collins, Joseph & Bielaczyc, 2004), giving focus to the kinds of questions DBR studies can reasonably address: When is an initial implementation of an educational innovation successful enough to merit further investment in perfecting the innovation? When is it successful enough to warrant implementation and testing on a large scale? What generalizable knowledge about the conditions and reasons for success can be gleaned from a DBR study, and how can we use this knowledge to support effective translation of a successful innovation into a range of new contexts? Our symposium addresses whether the DBR research enterprise can be improved and leveraged to help discover generalizable scientific knowledge of the type needed to develop successful educational innovations and understand them well enough to support their full-scale implementation.

Whether general scientific knowledge can be harvested from DBR is, however, a subject for debate. DBR crafts innovations by working within educational contexts that represent a complex mesh of goals, content, technology use, principles of learning, teaching methods, and accountability systems that must be woven together and shaped to a particular environment. Because any measure of success reflects the whole of the interacting variables that comprise the complex system, it is very difficult to isolate stable causal mechanisms within it or to translate lessons learned into other grade levels, students, schools, subject matter, types of technologies, etc. (Fadel and Lemke, 2006). For this reason, Anderson and Shattuck (2012) speculate that DBR may be more suitable for making and sustaining improvements in small-scale systems rather than contributing to large-scale and far-reaching systemic reform.

Yet DBR is increasingly called upon to fill an important niche in the array of methods now used to improve educational practice and create generalizable principles about it (Collins et al., 2004). For example, The Institute for Educational Studies (IES) currently funds ideas for educational innovation at several stages of increasingly larger funding, with DBR often the preferred approach for early and middle phases of an innovation's history. DBR in these phases helps perfect and test a theoretically designed innovation, providing evidence pertaining to its local success as well as implementation experience to support an informed translation, if warranted, into increasingly larger-scale contexts. Eventually, randomized experimental trials may produce generalizable judgments about an innovation's effectiveness and, consequently, about the theory of learning upon which the implementation project was based. In this model, DBR, hypothetically, contributes to theory from a pragmatist's perspective: Theories about *learning in context* are proposed and evolve through their various instantiations within a DBR research program. Experimental trials then produce confirmatory evidence, offering generalizable judgments about an innovation's effect as well as evidence supporting the pragmatic value of the situated learning theory upon which the implementation was based.

However, this passage to educational research Nirvana through DBR is a slow, methodic, expensive pilgrimage and, as recent discussions of DBR acknowledge, fraught with challenges. In fact, reviewers of DBR progress have been hard-pressed to identify any such completed journeys. But before considering those challenges and how to address them, it may be worth a brief digression to consider an alternative case, that is, the result of a lengthy educational research enterprise that did not build on a meticulous build-up of theory and implementation knowledge that DBR research strives to achieve. Consider, for example, the hundreds of studies of the effects of technology that have been conducted across a wide variety of educational settings over the last several decades. Many studies have been aggregated in several influential reports—e.g., ACT Policy Report: Evaluating the Effectiveness of Technology in Our Schools, 2004; Cisco Systems/Metiri Group Technology in Schools: What the Research Says, 2006; Milken Exchange on Education Technology, 1999; and the National Middle School Association Research Summary: Technology and Learning, 2007 (Fadel & Lemke, 2006; Noeth & Volkov, 2004; Schacter, 1999). These reports consistently acknowledge that using technology provides a small but significant increase in learning across all uses in all content areas, but they offer little guidance for implementation and include substantial caveats. Has a torrent of research on educational technology produced only a trickle of knowledge?

One problem relates to the inadequacy of the research methodologies employed to reach conclusions. “Most studies on the effect of educational technology on learning are correlational studies,” wrote Fadel and Lemke (2006). “Although such studies suggest what is working, they do not control for confounds that may provide alternate explanations for results.” Also, perhaps we have been mired too long in fruitless atheoretical research that engages experimental and statistical control to focus on effects of single features, such as “uses technology,” that are largely meaningless when considered separately from the complex, interacting factors comprising an entire ecology of teaching and learning. “Results and conclusions must be considered in the context of the interdependent set of variables in which the use of technology is embedded” (Fadel & Lemke, 2006). The unfolding DBR narrative is largely a research community’s response to this realization, and the story of its aspiration to carry out credible, theoretical scientific research of pragmatic significance in complex natural settings.

Unlike the experimental psychologist, who controls all aspects of an environmental recipe including the specific added ingredients associated with causal hypotheses about cognitive mechanisms, the DBR researcher eschews introducing artificial controls into educational environments. What DBR teams do is infuse an established educational ecology with new ideas and creations (an ‘innovation’), having in mind some theoretically derived hypotheses about how such infusions will alter the landscape to effect positive learning outcomes. Then begins the business of systematically studying that dynamic landscape in action, perhaps before but certainly during and after the innovation is introduced, searching for clues that will lead to an understanding of how the innovation and the ecology coalesce to effect learning. Researchers crisscross the landscape to collect data for analyses based on their hypotheses and a priori research questions, but they also attempt to capture other interactions that emerge as interesting, to increase the likelihood of fruitful unanticipated discoveries (e.g., Derry et al., 2010). In this effort to leave no potentially important stone unturned, DBR researchers typically document an innovations’ development and implementation history with detailed descriptions of situational contexts, rationales for designs and design changes at different phases, and learning and process outcomes. The overwhelming result is that every DBR project produces a substantial data collection. A widespread criticism and controversial issue dogging DBR is that it typically generates volumes of data that are never used.

One reason for this current state of affairs is that there are few agreed-upon standards, goals or structures to guide DBR scholars on what data to collect and archive. In addition to being unwieldy in size, DBR datasets are shaped in content and structure by whatever unique research questions and systems for data collection and archiving that an individual project or research group devises. Uniquely structured, unpublished datasets cannot be accessed or utilized, without great difficulty, by researchers and educators from outside the

project. It is even less likely that such datasets will be combined and aggregated for analytic purposes. In fact, the DBR research enterprise, in all respects ranging from the formulation of research questions to the archiving of data, is so fragmented that sharing and advanced data mining, which could address important theory-based questions across many projects, are difficult to impossible.

In discussing both promises and threats to the impact of “design-based implementation research,” Penuel, Fishman, Cheng and Sabelli (2011) argued that it is time to develop DBR as a more systematic form of inquiry and practice. They believe the DBR community must develop better norms and practices for theory development and for specification and testing of claims. They also called for developing standards regarding how evidence is used to guide design refinements, and practices for incorporating into studies multiple points of view and conflicting interpretations of data. Finally they suggested standardized use of design rationales in the manner that professionals in fields such as architecture, urban planning, and software engineering articulate such rationales to clarify the purposes and history of the design process, and to help them reflect on and modify designs. Design rationales could serve to make public the ways that educational teams employ evidence to resolve conflicts, weigh competing approaches to improvement, and identify new areas of focus for their work. Penuel et al. (2011) echo similar appeals by other analysts of DBR research. Collins, Joseph and Bielaczyc (2004), recently cited in Anderson & Shattuck (2012), previously advanced the idea of a DBR infrastructure to support data archiving, sharing and collaboration. Noting that design experiments produce large amounts of data that go unanalyzed, they called for an infrastructure to allow researchers from outside the original design team to access and analyze the data collected in large studies. Not surprisingly, Anderson & Shattuck’s recent review (2012) failed to uncover any evidence of such sharing currently taking place. Such sharing would require the DBR community to have standard protocols and systems for archiving of data in a format that supports multiple forms and levels of access, sharing and analysis, while adequately protecting the privacy and identities of human subjects.

## Purpose of Symposium

The organizers of this symposium believe the learning sciences community would be well served by mutually creating an infrastructure to encourage and support collective engagement by multiple design-based researchers in working toward answers to important theory-driven research questions, moving our field toward a “bigger science” approach. It is in this spirit that we reach out to members of this community to join with members of other relevant fields, such as computer science, in an effort to design, build, support and participate in a mutually established cyberinfrastructure and user community for DBR. This symposium would continue the organizers’ NSF-sponsored effort, begun at a recent CSCL 2013 workshop, in which we vetted one concrete proposal to organize a group of participating researchers around designing and using a common suite of Internet-based workflow visualization tools that would impose flexible but agreed-upon standards for data collection and ways of working (Hackbart, 2011; Hackbart, Derry, Eagan & Gressick, 2010). In this ICLS symposium we call for additional proposals as well as reflections and critiques on proposals put forth and the enterprise in general. One question that emerges from our work so far is whether a primary goal of this endeavor should be to support the work of junior scholars. These are the issues that the collective presentations in this symposium, which was designed to include scholars at various career stages, will address. This goal fits well with the stated conference theme to “focus on practices that pertain to how we organize our own work as learning scientists: the practices for analyzing and modeling learning across settings and time and the practices for designing for scale and sustainability.”

The presentations that follow each bring a unique perspective in discussing how a well-developed line of inquiry might inform the design of a DBR cyberinfrastructure. Hackbart’s presentation will supply an “object to think with” in describing how developing data analytic tools based on workflow visualization provides one feasible way to proceed. Richard Lehrer will contribute years of experience conducting design-based research in schools by sharing his team’s practice of creating “design documents.” In discussing the strengths and limitations of design documents, he suggests that the next phase of DBR must focus on instrumentation to permit tracking of design trajectories at a larger scale, so that theory development can follow. Katerine Bielaczyc will draw from cases of distributed DBR with Knowledge Building Communities to examine the usefulness of the Social Infrastructure Framework as a basis for defining data categories and metadata tagging within a cyberinfrastructure. She will also consider how a cyberinfrastructure enterprise could support early and low-resource researchers. Gonzalez and Sandoval will describe a needs analysis for graduate training of design-based researchers, examining what features of a cyberinfrastructure project are needed as support this effort. Discussant Allan Collins will offer an integrative commentary on these proposals and the enterprise in general.

In 2004 Chris Dede challenged the DBR community to engage in an evolutionary dialogue about the purpose and processes of DBR that would define DBR in a realistic way. He was not optimistic that the community would be able to do so at that time. But perhaps the time is now.

## **Workflow, Information Visualization, and the Potential of Cyberinfrastructure to Manage Design Based Research**

Alan J. Hackbarth, Sharon Derry and Sadhana Puntambekar

According to the Design-Based Research Collective (2003), the critical characteristic of design based research is that the central goals of designing learning environments and developing theories or “proto-theories” of learning are intertwined. Development and research takes place through continuous cycles of design, enactment, analysis, and redesign, and research must account for how designs function in complex authentic settings – not only in terms of success or failure, but also in terms of interactions that refine understanding of the learning issues involved. One needs a well-developed profile of an implementation in order to analyze a design in terms of its key elements and their interactions, but this is challenging because of the number of variables to account for and the diverse people involved at different levels of design implementation. Given this complexity, design researchers usually end up collecting large amounts of data, more data than they have time or resources to analyze.

Addressing these issues, Hackbarth will discuss the NSF-sponsored work our research team is undertaking to co-opt and develop data-analytic tools into a cyberinfrastructure that gives researchers leverage to organize and access layers of complex data in a way that facilitates analysis and deeper understanding of learning in authentic settings. This work began with development of the Workflow Visualization System (WVS) (<http://vmc.wceruw.org/workflow/workflow.html>), a prototype that utilizes workflow concepts from business and science, information design principles (i.e., Tufte), and web interactive tools to document the design and implementation of units of instruction. The WVS was vetted at a workshop of DBR researchers at CSCL 2013 in order to stimulate discussion of the pragmatic challenges of doing DBR and suggestions/specifications for a cyberinfrastructure tool that will address the challenges. Issues raised at the workshop included the need for an interface that provides: access to and makes clear the rationale and goals of a design to all parties (e.g., researchers and teachers); flexibility to document a wide range of elements and structures of a design and their interrelations, and to document design changes that occur during implementation; reduction in time-consuming processes of data collection, archiving, and retrieval; and ways of connecting designs and data to questions/propositions/theories.

The emerging tool is a synthesis of course management functionality from Moodle and semi-automated visualization functionality from the WVS. A user will have the ability to write a specification of the research project, including hypotheses, assumptions, theoretical framework(s), research questions, context, and so forth, and create any number or types of fields to collect data about a designed intervention. Researchers will then be able to use a drag-and-drop tool to create a multi-layered visualization of the intervention and associate data fields to each part of the visualization. (See Figure 1.) They will also have the ability to annotate each part of the visualization. As a designed intervention takes place, learner-generated data will be added to the visualization. All information and data will be accessible from the visualization by mouse-overs or clicks on icons. The overall purpose of the tool is to make visible in one place the interconnections among elements of the intervention and provide access to data about, or generated from, each element of the intervention.

This presentation will describe and show examples of our emerging cyberinfrastructure tool for managing the processes of DBR, and how it may contribute to codifying standards and moving DBR from a collection of methods to a methodology.

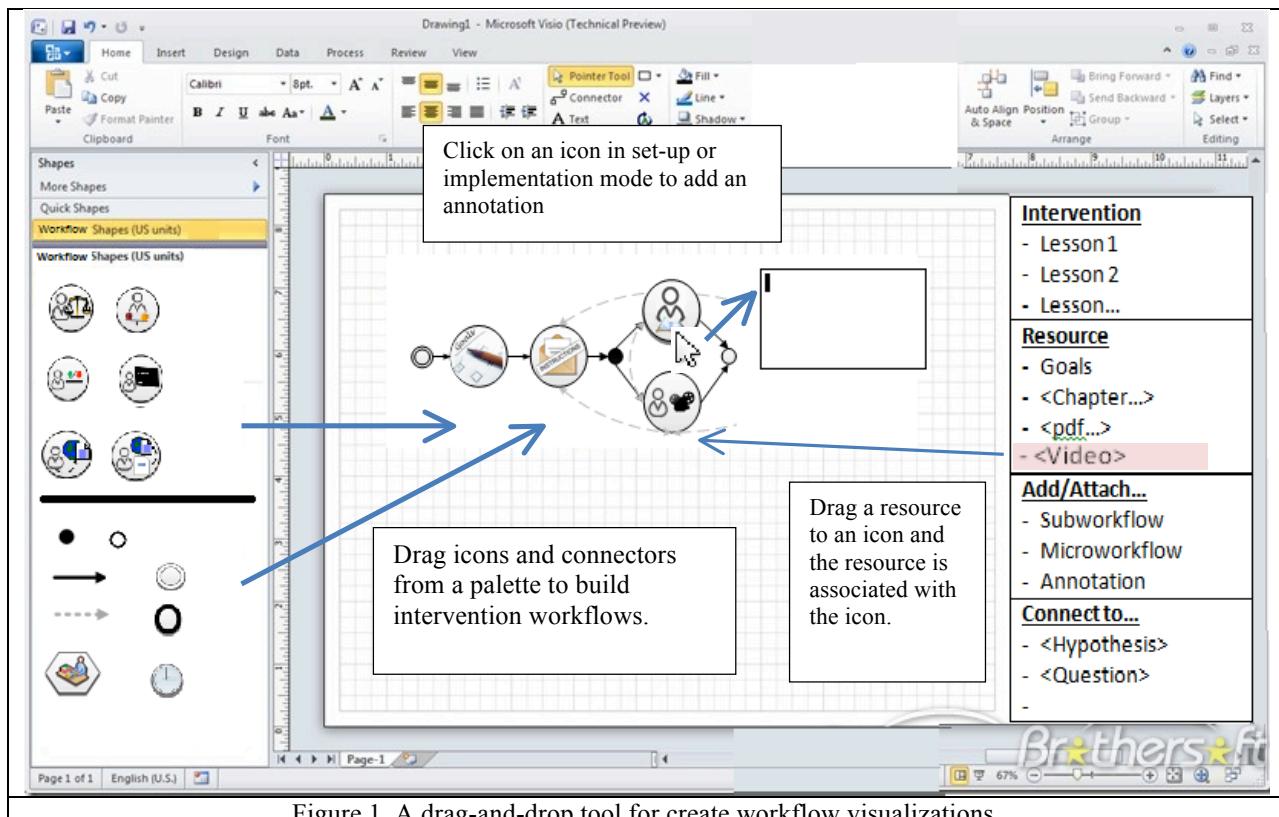


Figure 1. A drag-and-drop tool for create workflow visualizations.

## Knitting Designs Across Venues and Contexts

Richard Lehrer

Design-based research is now acknowledged as a useful and powerful framework for generating and testing “modest” theories of how particular innovations function in particular settings. Yet there is a persistent press to elevate designing to the status of method, with attendant clear guidelines and prescriptions for practice. This press for method may have the unintended consequence of exchanging the flexibility and responsiveness essential to the conduct of design-based research for the apparent rigors of method. A more productive elaboration on design-based research would be to develop tools that make the process and products of design more transparent and that are useful to the process of design. First steps in this direction have been taken, as indicated by the participants in this symposium. For our part, we have established a practice of constructing “design documents” that describe essential elements of a learning ecology and the ways in which these elements are orchestrated to increase the probability of learning in particular ways for particular purposes. Design elements include: 1. the nature of the tasks/problems that are either posed to participants or are likely to be generated by them; 2. the representational and related symbolic systems that participants either appropriate or invent; 3. the material means of production available; 4. the modes and means of argument that are privileged in the system, and 5. the activity or participant structures that are likely to influence exchange among participants. Interactions among these elements of design constitute prospective mechanisms of learning, and these interactions are intentionally supported in classrooms or other deliberately designed ecologies.

Design documents also describe the nature of evidence about and for learning. Reflecting on our practice, design documents appear adequate for rendering forms and spaces of learning that are characterized by modest scope—those that can be traversed within days or perhaps a few weeks of instruction. For more ambitious efforts, such as designing learning progressions or other endeavors of more significant scope, design documents are difficult to sustain. One problem is that efforts of larger scope—as in longitudinal research extending over years, or coordinating design of professional development and its temporal patterns with that of students—require tools that allow one to visualize relations between otherwise distinct design efforts. Moreover, designs for learning that are extended in time require ways of tracking prospective trajectories of change at individual and collective levels. In my talk I will suggest that the next phase of design-based research needs to be one focused on instrumentation, and that instrumentation needs to lead so that theory development can follow.

## **Using the Social Infrastructure Framework to Guide Data Collection and Tagging Metadata in Building a Cyber-infrastructure for Design Research**

Katerine Bielaczyc

In carrying out design research involving technology-based tools, it is critical to extend the design process beyond the tool itself to consider the elements of the broader classroom learning environment. The social structures of a classroom play a key role in such a design. The Social Infrastructure Framework (SIF) specifies a set of critical design variables concerning classroom social structures (Bielaczyc, 2006). The top-level variables include:

- *Cultural Beliefs*
- *Practices*
- *Socio-Techno Spatial Relations*
- *Interaction with the "Outside World"*

In turn, each top-level category has sub-variables. For example, Practices includes sub-variables such as *the associated participant structures of students and the coordination of on-tool and off-tool activities*.

In creating a cyber-infrastructure for Design Research, the SIF can be used to guide both (a) the data collection activities of distributed researchers working toward common design goals, and (b) the tagging of metadata in storing the data collected across multiple projects. Looking at a variety of classroom implementations through the lens of the SIF would make such design decisions explicit and permit design elements across these settings to be classified into a common form, providing a systematic basis for comparisons and contrasts.

Further, because these data archives would provide a rich representation of various classroom social structures, researchers not involved in the original research may be able to study questions of their own choosing concerning the social structures in a particular setting. That is, through tagging meta-data across multiple design experiments, they may address new questions beyond those posed by the original researchers. What an educator, anthropologist, cognitive psychologist, or media designer will see when they look at the data from a particular design experiment or across a variety of design experiments will be very different. When different eyes look at a design, it provides a kind of triangulation that we do not often find in reports on design experiments. Instead of analysis using different sources of data, this kind of triangulation would provide different theoretical perspectives on the same data.

In addition, such an archive would allow researchers, who are just starting their careers or who are located in places with few resources, to carry out their own research with a rich data source. This would give doctoral students the possibility of carrying out design research with a deep disciplinary focus. Their analysis would be set against the multi-disciplinary analysis of the original researchers, which would promote learning of the broader issues, while maintaining an emphasis on the methodological concerns of their own discipline. Their training would embody disciplinary analysis in a multi-disciplinary context, and hence they might get the best of both approaches to training.

In the presentation, I will discuss various issues that arise in using the SIF to guide both data collection and the tagging of metadata. I will draw from various cases, including the corpus of classroom data collected by researchers involved in distributed design research with the Knowledge Building Communities model (Scardamalia, 2002; Scardamalia & Bereiter, 2006).

## **Learning to do Educational Design Research: A Needs Analysis**

Carlos Gonzalez and William A. Sandoval

In the writing on educational design research that has blossomed over the last decade, there is little articulation about how to train new researchers to conduct educational design research. We present a needs analysis for graduate training in educational design research, derived from a synthesis of available writing on design research as a method and our own experiences in doctoral training. The analysis identifies areas where newcomers to the learning sciences require training to conduct design research that moves the field forward, while leaving open the questions of how to best provide such training. Obviously, learning to do design research entails overlaps with graduate training in educational research more generally, including selecting good research questions, reviewing relevant literatures, and methods and research design. We see design research as complicating this research training in two respects. First, there are the particulars of work that change through *phases* of educational design research, from problem analysis, design, and enactment, through retrospective analysis. Each phase carries particular training demands. For example, problem analysis typically requires the synthesis of literatures, often across a range of disparate fields, to understand the background to some learning problem and previous efforts to solve that problem. It may further require a local needs analysis in the specific intended context of work. Similar demands, unique to design research, arise in each phase.

A second respect in which design research requires particular training is related to *trajectories* of design research. The majority of writing about design research assumes a linear trajectory of increasing scale, akin to clinical trials in medical research and familiar to educational intervention research generally. Yet, an analysis of design research as it has been carried out over the last couple of decades reveals a diverse family of approaches to design research, with their own particular trajectories suited to the pursuit of particular sorts of questions. Important and notable design research is best characterized in terms of increasing depth rather than scale, and this difference in focus carries implications for the research methods one uses across design studies. These families of design research may differ in their emphasis on the joint goals of understanding processes of learning and teaching and understanding innovation, and such emphasis can change across a trajectory of work. These demands require new design researchers to be well trained in a variety of qualitative and quantitative methods in ways that are linked to phases and trajectories of design research. We will present the details of our needs analysis in terms of training requirements for doctoral training. The analysis will suggest features of a cyberinfrastructure that could support such training.

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## **Acknowledgments**

Some of the work reported in this symposium was supported by NSF Grants DRL 0822189 and IIS 2127027. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

# **Is the Sum Greater than Its Parts? Reflections on the Agenda of Integrating Analyses of Cognition and Learning**

**Co-Chairs:** Mariana Levin, Michigan State University; Orit Parnafes, Ben Gurion University  
**Discussant:** Timothy Koschmann, Southern Illinois University

**Presenters:** Andrea A. diSessa, University of California, Berkeley  
Mariana Levin, Michigan State University  
Reed Stevens, Northwestern University  
Rogers Hall, Vanderbilt University  
Joshua Danish, Indiana University,  
Noel Enyedy, University of California, Los Angeles  
Orit Parnafes, Ben Gurion University

**Abstract:** This symposium springs from an ongoing effort to bring together contrasting methodological perspectives for the study of human knowing and learning. Specifically, we build bridges between two significant process-oriented approaches: Interaction Analysis (IA) and Knowledge Analysis (KA), to study how individual cognitive dynamics interacts with complex social dynamics. We demonstrate the kind of insights and outcomes of such integration, by zooming in, and explore two specific efforts to bridge KA and IA. Both focal pairs of analyses in this symposium make central use of the theoretical construct of coordination class, a theory is associated with KA usually used for analyzing the structure and dynamics of an individual conceptual system. Coordination class theory is used to extend an IA analysis in the first pair of analyses, and is elaborated on using IA methodology in the second pair. The presentations aim to stimulate discussions about the merits and constraints of such integrations.

## **Symposium Overview**

An increasing body of evidence in the cognitive and learning sciences has led the field to recognition that human knowing and learning is incredibly multi-faceted in nature. Over the past decades, the field has come to understand more deeply how cognition and learning are embedded in social context, structured by both cultural forms and assumptions and by interaction with physical artifacts. Given this diversity in forms of complexity, it is not surprising that historically different intellectual lines have pursued diverse directions, drawing upon characteristically different methodological and theoretical assumptions. While multiple perspectives can offer depth and richness to our understanding of learning processes, there is a need for an increased focus on purposeful synthetic work in the learning sciences that can enable us to develop theoretical or empirical bridges across perspectives. The current lack of articulation across perspectives is both scientifically unsatisfactory and also has important consequences with respect to educational design, one of the central enterprises of the learning sciences.

The current symposium is part of a larger, ongoing effort to bring together contrasting theoretical and methodological perspectives on learning (Brown et al., 2012; diSessa et al., 2010; diSessa, Levin, & Brown, under review). In particular, we are currently focused on building bridges between two significant process-oriented approaches to studying knowing and learning: Interaction Analysis (IA) and Knowledge Analysis (KA). This work is centered on the innovative and challenging agenda of studying how the dynamics of individual cognition interacts with complex social dynamics. The aim is in this work is to be mutually accountable to issues of both knowledge and interaction in analyses of cognition and learning. Some of the central prospective outcomes of the agenda to articulate and integrate perspectives include:

- Extension and refinement of lines of research that were originally developed from one (KA or IA, in this case) perspective.
- Re-situating central constructs, with respect to new a contrasting perspective in a way that can result in expanded meaning for theoretical terms or extending the range of previous empirical results.

The current symposium gives examples of both of the above kinds of outcomes of integrative work. We examine in detail two cases of bridging KA and IA in an attempt to better understand processes of learning in interaction. We now give brief descriptions of the two methodological perspectives that are the focus of this symposium: IA and KA.

Interaction Analysis, **IA** (Jordan & Henderson, 1995) provides methods that have been used to study conceptual learning and teaching as mutually-accountable, purposeful activity (e.g., Hall & Greeno, 2008;

Stevens, 2010; Stevens & Hall, 1998) that is accomplished through the sequencing of conversational turns, the monitoring and repair of understanding, and how talk is designed with a recipient in mind. IA methods draw upon foundational work in linguistic anthropology, ethnomethodology, and Conversation Analysis (e.g., Garfinkel, 1967; Goffman, 1967; Goodwin, 1994; Goodwin & Heritage, 1990; Sacks, Schegloff & Jefferson, 1974). Knowledge Analysis, KA (diSessa, 1993; 2004; Parnafes & diSessa, 2013, and Sherin, 2001), focuses on the nature and form of individual knowledge systems: what they are comprised of, how they are organized, and how this organization changes over time in interactions with the physical, social, and material world. KA has intellectual roots in developmental psychology (Piaget, 1930) and computational modeling (Newell, 1980) and is primarily concerned with elucidating the form, content, and dynamics of knowledge through the study of episodes of moment-to-moment processes of thinking and learning. Both perspectives rely upon video records of actual learning interactions, pay attention to what happens on a moment-by-moment basis, look for contextuality, and try to account for shifts in contextuality.

## The Structure of the Symposium

In this symposium, we zoom in and explore two pairs of analyses in detail. A point of synergy between these two pairs of analyses is the way that they, in very different ways, draw upon and extend the theoretical construct of a *coordination class* (diSessa & Sherin, 1998). A coordination class is a particular model of a concept, the function of which is to read out a concept-characteristic class of information across the many situations in which one encounters the class of information in the world. Coordination class theory is associated with KA and is usually used for analyzing the structure and dynamics of an individual conceptual system. Coordination class theory is used to extend an IA analysis in the first pair of analyses, and is elaborated on using IA methodology in the second pair.

The first pair of analyses originated from a study drawing on IA methods by Stevens & Hall, exploring the notion of disciplined perception documented in Stevens & Hall (1998). Drawing on this data set, Levin & diSessa add a KA layer, to explore disciplined perception and the interactional practices underlying its development through a coordination class theory lens. Following Levin & diSessa's analysis, Stevens & Hall will respond, providing both context for the original analysis and a current view from their perspective. In providing context, they will also elevate features of their methodological approach in the original analysis.

The other pair of analyses originated from a KA study by Parnafes using coordination class theory, documented in Parnafes (2007). Parnafes will highlight the principles behind the KA work she did in analyzing the development of conceptual understanding through the interaction of a pair of students with a computer simulation. Following this, Danish, Enyedy, and Parnafes focus on a small episode of student interaction from the same data-set Parnafes studied in order to use IA tools to explore the interactional patterns between the students as they constructed new understandings.

In closing, our discussant, Timothy Koschmann, will reflect upon the integrative agenda as it is exemplified in the four presentations.

## Disciplined Perception Through the Lens of Coordination Class Theory

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### Introduction

We explore the agenda of integrating accounts of learning developed via contrasting analytic and theoretical lenses. In this paper, we use coordination class theory (diSessa & Sherin, 1998) to reconsider an analysis of learning processes originally conducted by Stevens and Hall (Stevens & Hall, 1998). We start from the same episodes they identify as instances of "disciplined perception" and processes of "disciplining perception." Our analysis resulted in building an individual level analysis into the existing interactional account. In this paper, we reflect on the affordances of building integrative accounts through such layering of analyses.

### Background and General Results of the Original Analysis

Stevens and Hall introduced the term "disciplined perception" to capture the ability of experts to "quickly register features that are relevant to their particular practice, features that are invisible at a glance to non-experts" (Stevens & Hall, p. 108). Beyond this, disciplined perception encompasses "active and embodied practices" typically extending over time and across people and things by which individuals bring heterogeneous elements (e.g., various representational media) into coordination. To study processes by which perception is disciplined, Stevens and Hall document "naturally occurring sequences in which people assemble and coordinate aspects of visual displays to make practically relevant objects of conditions visible to themselves or co-participants" (p. 108). One of the outputs of the analysis in Stevens & Hall, 1998 is a first-order model based of how learning through interaction or "disciplining perception" occurs: Joint activity progresses until a breakdown of communication is noticed (usually by the more experienced participant). This breakdown in

communication then leads to intervention and attempts at repair by the more experienced participant. In this interactive process of repairing breakdowns in intersubjectivity, the perception of the less experienced participant is shaped and becomes more disciplined.

### **Integrative Potential and Foundations**

Despite historically different theoretical and methodological lineages, in a fundamental way, Stevens and Hall's disciplined perception and diSessa's coordination class theory share important features that make them amenable to a "dialectical" or "integrative" analysis. Firstly, the social practice level description of competence given in Stevens and Hall, 1998 is not incompatible with the informational processing description given in diSessa & Sherin, 1998. Both perspectives on expertise and its development focus on the role of perception. Both perspectives develop their theoretical accounts through the analysis of data of real-time processes of reasoning. For both, what individuals are attending to and noticing in real-time is of critical importance. The original analysis of disciplined perception, done by Stevens and Hall, gave primacy to the way perception is shaped through social and material means. In reformulating disciplined perception from a coordination class theory perspective, our approach is to build from their analysis, examining in more detail what, exactly, individual participants need to see, and how they do so, in particular learning interactions.

Stevens and Hall use two contrasting focal case studies to illustrate the nature of disciplined perception and how it develops: the case of Adam and Bluma, involving a young algebra student learning about linear functions via interactions with a computer program and a tutor and the case of Jake and Evan, concerning two professional, yet differentially experienced, roadway engineers working together on producing a justification for a design of an overly steep roadway. Though we have analyzed both cases through the lens of coordination class theory, for reasons of space, we focus only on the case of Adam and Bluma in this paper.

### **Sample Analysis: The Case of Adam and Bluma**

Stevens & Hall (1998) analyze segments of an extended tutorial interchange between an experienced algebra teacher/tutor, Bluma, and a young algebra student, Adam. Adam has been working with some graphing software to explore the connections between equations, the lines they correspond to, and various points and intervals on the graphing plane. Adam comes to rely upon a particular representational form in order to solve the problems posed to him such as those that involve determining the relative locations of points and lines (e.g., whether a given point is on a line or not). The representational form in question is "grid view" a conventional pair of crossed axes, but with dots added to mark grid points, mainly at integer x, y locations. Adam uses this framework exclusively, and when Bluma tries to provoke him to use alternative strategies, he persistently does not know how, and he also makes clear that he does not see the point of alternative strategies.

A focal case is the task of deciding whether a point is on a given line. To solve this problem, Adam draws a line by marking a few "representative" points on it, for example,  $x = 1, 2, 3$ , computing the corresponding y values from the equation (of the form  $y=mx+b$ ). Then he sketches the implied line, and merely observes whether the point in question (also plotted on the graph) is on the line or not. Although Adam clearly knows how to identify points by their coordinates, and he can also determine coordinates, given a plotted point, he systematically does not, and claims he cannot, use the equation directly to determine whether a point is on the line corresponding to a given equation. To Bluma, as a mathematically more experienced participant, physical graphs are ancillary, and one can easily "see" whether a point is on a line by evaluating the y corresponding to the relevant x using the equation, verifying that the computed y matches the y from the point in question. Finally, Adam realizes how he can use the equation of a line ( $y=2x+5$ ) directly to check whether a given point (3, 8) is on it. This occurs after several attempts by Bluma to keep the grid view out of consideration, hoping Adam will then turn to the simpler and more epistemologically fundamental equation strategy by himself. She never suggests any details of how one does this; she only says that there is another way to determine whether a point is on a line that does not use drawing lines and plotting points.

In viewing the above events through a coordination class lens, we first identify the relevant coordination class: the determination of object location. Here, we intend both "object" and "location" in an extended sense, including things like points and lines in Cartesian space with respect to one another. Stated another way, the competence at stake involves the kinds of strategies by which people "see" where things lie with respect to one another. In this case, Adam merely "observes" the spatial relationship of a given point and a line. First, he must instantiate the relevant point and line, as opposed to simply determining their relative location where they happen to lie. This is easy for Adam—and he knows it; he knows how to plot (position) points and lines, given coordinates of a point and the equation of a line. Determining (observing) a spatial relationship, the critical coordination class operation here is easier than in many cases of determining relative position, since the only relevant determination is "point on line" or "not." Assimilating the work Adam does in response to point-on-line questions to the "relative spatial location" coordination class does two pieces of work for us. First, it explains why the method he uses is so simple and obvious to him. (First, you put things where they belong, and then you observe their relationship.) Second, it helps explain how natural Adam found this

method and why he found the possibility of other strategies so foreign. How else can you determine spatial relationships without observing? Why would you want to?

## Discussion

While Stevens and Hall emphasized Bluma's role in Adam's learning, the coordination class analysis encourages us to reflect on the fact that Adam noticed something. Bluma did not draw his attention to it, except in the general sense of putting him "in the vicinity" of the thing to notice. At that moment, it was his choice to select  $x=3$  to enact the procedure to sketch the line, unintentionally matching the  $x$  coordinate of the point under consideration, allowed him to notice that this would give a general method to solve such point and line problems. We conclude that we can only partially credit Bluma with "disciplining." The rest of the credit goes both to chance, and to Adam's ability to notice this particular thing and see its generalization. Not every student will be able to do this, so we *must* have a way to talk about individual differences between the organization of Adam's knowledge system and others' if we are to be able to predict insight and, hence, development. Our analysis points to the need to complexify the determinism implied by the first order interactional model of disciplining perception through negotiating breakdowns in intersubjectivity given in the original paper.

Our analysis is not merely a complementary analysis to Stevens and Hall's. We considered the same data and the same phenomenology within the data: the nature of technical competence and how it develops in interactions between people. The implications for the integrative agenda seem to be that two-phase analyses (in this case, first an IA account of knowing and learning, followed by a KA analysis) can lead to an enriched account that draws upon both phases of the analysis. The second phase of analysis, illustrated here, seeks to extend a previously identified theoretical idea, disciplined perception, by providing a glimpse of what is going on beneath the surface of observable actions. Our general approach has been to explicitly build on and locate within an analysis done from an IA perspective, issues that can be illuminated by a KA perspective. Thus, though the second phase of analysis we produced is not itself an integrated analysis, we see this process of layering and elaboration of analyses as serving an instrumental role with respect to the larger integrative agenda.

## Yipee KAIA and other Cowboy Expressions of Joy

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## Appreciations

We start by appreciating the spirit of exchange evident in Levin and diSessa's effort to re-analyze a fragment of interaction from our earlier chapter on "disciplined perception" (DP), using a theory of coordination classes consistent with their approach to *knowledge analysis* (KA). We have left Adam, Bluma, Jake, and Evan behind us, but they are still richly present in our analytic imaginations—this is the sort of durability of memory you get by engaging with *interaction analysis* (IA) of learning.

## Some History

Disciplined perception is a concept built out of close analyses of video recorded cases of people in interaction, engaged in complex sociotechnical practices. Our interest in putting this concept into circulation was, in part, corrective, as theoretical work often is. At the time the paper was written and revised (between 1992 and 1998), the field we now call the learning sciences mostly cared about learning and knowing in disciplines, particularly in math and science. In the work we were doing, prominent accounts of cognition and learning left out too much that mattered to how people learned and used knowledge together. These accounts were richly furnished with actants of the mind—schemas, concepts, sub-goals, productions, p-prims—but were anemic when it came to actants of the observable world—voices in conversation, computer screens, drawings, pointing fingers, moving hands, and noticing eyes. We wanted to correct this, to provide a theoretical alternative.

## Our Alternative (Then) and Agreement (Now)

Borrowing techniques and principles from conversation analysis and ethnethodology we attended to observable actions and interactions, and moreover to what participants in interaction were noticing, seeing, using, and making matter to themselves and to each other. What we were studying after all were *their* interactions. That we refrained (for the most part) from looking past the observable actants (turns at talk, hands in motions, computer screens, drawings, gestures, pointing, etc.) into the world of mental actants that are so readily visible to many cognitive scientists was indeed part of the corrective. That being said, we held no epistemological or ontological stance (nor do we now) that rules out a parallel and integrated account, one that seeks to argue for durable interior resources we 'acquire' and carry around with us that give shape to our actions. We remain skeptical about how observable actants and actions can be *seen through* to provide a confident account of interior actants and processes. But Levin & diSessa make a creative attempt to take our account of the observable actants in interaction more or less as we provide it and then speculate on mental

actants that they would argue are present and at work, operating “beneath the surface of observable actions.” The devil is in the details, but in principle we share with our colleagues here the goals of an “integrative account.”

## Some Details

We have chosen to focus on two points where the details Levin and diSessa’s analysis depart from ours in ways that matter theoretically. These are treating Adam’s grid calculus as a pre-classified way of thinking and arguing that our DP concept is simple and deterministic as an account of learning and teaching.

*It’s a “grid calculus” not a “particular representational form.”* What we called Adam’s “grid calculus” provided him with a way of dealing with problems posed by Bluma, the software in the tutorial interaction, and their tutoring conversation over time. At least for a while. It was not a “particular representational form” in our thinking and analysis. That was a substantive theoretical point. By calling it a “calculus” we deliberately wanted to draw attention to its history and powers, a discovery or invention that was *his*. The coordination class analysis developed in the paper by Levin and diSessa pre-assigns the meaning and value of Adam’s activity to a “particular representational form” and pre-assigns a “simpler and more epistemologically fundamental equation strategy” to Bluma. This assignment of relative value of the two different practices for graphing functions *in these tasks as they unfold in time in these interactions*, though we do agree are different and said so, is not demonstrated or directly analyzed in the coordination class approach. It instead seems given before their analysis starts—not something for discovery in interaction *by* Adam and Bluma. This runs off the rails of our understanding of interaction analysis (with its CA and EM roots). So this is not a productive integration strategy, from our perspective.

*DP is an interactive achievement, not a way of shuffling individual mental contents.* One of Levin and diSessa’s central challenges to our interpretation, consistent with their view that our DP concept is simple and deterministic, is their claim that the tutor’s actions of ‘disciplining’ are only “partially” responsible for an observable change in Adam, implying that we were arguing they were entirely responsible, or otherwise “determined”. We did not argue that disciplining perception determines anything here or that Adam was particular determinable. And we find this interpretation of our view extremely hard to hold if we restore the storyline we painstakingly built up over an analysis of the previous seven episodes. Across those episodes we depict an Adam who is everything but malleable. We depict a young person who has found, uses, and tenaciously holds on a cognitive practice, which while idiosyncratic from a normative perspective, is his and moreover works in the practical context of the work that he is asked to do with the math problems. Our goal was to describe the actual observable practices of disciplining in whatever forms they took, which turned out to be diverse. (For an outright programmatic defense of a research program founded on documenting and studying this diversity, see Stevens, 2010). The strongest move the tutor Bluma makes in all the episodes is not deterministic at all; it seeks to block Adam’s use of the grid, a move oriented to having him try to ‘figure it out’ in a different way, presumably the conventional way. This happens only when she finally notices that he is using the grid calculus to “figure out” the problems, a practice that was until then seemingly all but invisible *to her* because of *her* disciplined perception that privileges the equations as a means for figuring it out. Our account is not simple, though we were refreshed by this suggestion since both of us generally face down the opposite accusation of rendering things too complex, even when we regularly find and show them to be so in the unfolding interactions of the people we study. Our account *does* include material and social actants that are explanatory, actants and observable phenomena that are (thus far) entirely missing from the explanatory vocabulary of coordination class theory or the use of KA brought to the re-analysis of the conversations and activities we analyzed.

Levin & diSessa’s reinterpretation focuses on turns at talk from a final episode when there is an articulated turning point in Adam’s practice, when he *finally* recognizes the possibility of using an equation. As we note, this is *Adam’s realization* and it should seem clear that we in no way suggest that Bluma *determines* this realization. However, we do make a point of highlighting that there is *interactional evidence* that she *influences* it. In the episode, the math problem involves how a hypothetical student Sue would determine if a point is on a line only expressed as an equation. In turn 4 of the episode, there is strong evidence that Adam thinks the route to answering involves deploying some version of the grid calculus. As in the previous episode, even though the grid is gone, he starts to actually restore it by drawing it, such is its robustness in this sociotechnical system for him. But then Bluma makes a hard insertion into his conversational turn that—while determining nothing—certainly conveys to him a sense that he should be doing something different. His answer is responsive to this move both in the way it starts with “oh well” and how it moves on to his own articulation of what “I *should* be doing”. So while we are fully in agreement with Levin & diSessa that Bluma does not determine the disciplining here, the question is whether such a hard pivot in his actions doesn’t provide good evidence of *influence*.

## **Looking Back and Forward**

We end with a question that has lingered in the ongoing conversations between our group and theirs and a wider set of colleagues represented in this symposium, all of whom are exploring the possibility of integrating perspectives. As is well known, most of the interior actants that populate ‘knowledge analysis’ accounts have been generated in clinical interview contexts. Those are contexts that rely on the view that a subject’s knowledge is probed and elicited by a skillful interviewer and rely as well on the idea that the knowledge that is displayed by subjects is not shaped in decisive ways by any particular thing an interviewer says or with what timing or prosody he says it. But this influence as an empirical possibility is the very premise of interaction analysis, to be shown, or not shown, in actual analyses of recorded interactions. So the idea that a non-explicit, non-deterministic conversational turn like Bluma’s could truly influence a shift in knowledge, as interactional evidence suggests it did here, might be perceived as a significant threat to a much larger enterprise.

## **A Coordination Class Analysis of Individuals in Interaction**

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In this presentation I will revisit the KA I completed a few years ago (Parnafes, 2007) with new attention to how knowledge analysis was employed to analyze the individual students’ understanding. I intend to abstract the principles of analysis and comment on the assets and limitations of that analysis. I will also examine the way that interaction and social context was taken into account in the specific KA.

The prior research investigated how computer-based representations facilitate the development of conceptual understanding in the domain of harmonic oscillation using coordination class (CC) theory (Parnafes, 2007; 2010). CC theory was used for the analysis of student understanding in this context because it enabled me to look at the process of conceptual change at a fine-grained level, with the aim of describing the mechanisms of developing understanding. In addition to the conceptual processes, CC theory refers to perceptual processes, and thus was particularly suitable for analyzing processes of learning in a learning environment rich in external representations. This also provided an opportunity to examine possible relations between representations and conceptual change.

The research included case studies, in which dyads engaged in learning activities to explore the phenomenon of natural harmonic oscillation through the interaction with physical oscillators and with a computer-based simulation. The choice to work with dyads rather than to use clinical interviews, which are typical in KA methods, was due to several reasons. First, it was important to establish a relaxed atmosphere in order to promote meaningful, productive discussions. Second, students who worked together expressed their thoughts verbally with no need for prompting. Third, interaction in dyads advanced the development of explanations since, in some cases at least, students challenged each other and asked questions about their partner’s explanation. The choice of looking at the interaction of dyads through learning activities, thus, created good opportunities for rich and high-quality data production.

The other side of that richness is that the analysis of conceptual understanding of two students interacting and affecting each other’s understanding, posed some critical methodological challenges. Coordination class theory accounts for describing the fine details of the architecture of an individual conceptual system and its development. But in the case of the interaction of two students, the evolution of each individual’s coordination class was a function of the interactional activity between the students, resulted in a complex system of collaboration. In such a setting, the researcher has to deal with the complexity introduced by having two conceptual systems interacting with each other, and with a material environment.

As an example for this complexity, and the way I handled it using CC theory in the KA tradition, I use one episode of a case study from this research. In this case study, two 10<sup>th</sup> graders explore a simulation that has multiple representations of natural harmonic oscillation. They work with the simulation to explore how to make the oscillator go fast. Throughout the episode, the two students seem to act as if they share the same understanding, and they collaborate on this task almost with no disagreements or breakdowns.

The focus of a knowledge analysis would be primarily conceptual, analyzing the structure of the students’ knowledge and how this structure develops as the activity unfolds. In the case of the interaction between students, I considered two choices for analyzing the two students’ conceptual systems. One option was to treat each student’s conceptual system separately (considering and treating as relevant the input from the interacting person). The other choice was to treat both students together as one system, assuming both students are on the same page. In the analysis I did, when it was apparent that the two students were thinking and reasoning differently, one student’s conceptual system was analyzed separately, with the other student taken into consideration as providing inputs for the conceptual processes of the analyzed student. When the students were in sync, the analysis focused on both of them together, as if they formed a “shared” conceptual system.

Here is an example from the analysis, taken from Parnafes (2007). The students try to figure out what “fast” mean in oscillatory motion using a computer-based simulation. They are now working with the simulation and experimenting with different parameters of the simulation. On the computer screen there is a velocity versus

time graph, as well as other representations. One of the students, Robin, points with the mouse to areas on the graph and says:

"These are the same skinniness level but they are not as high." She compares the graph appearing on the screen to a graph appeared previously with a different parameter value. Following this utterance, there was a short interaction between the two students that led them to re-check the previous representation, and verify and consult with each other. However, the inferences made after this exchange was similar to the first inference made by Robin.

The KA analysis of this segment in Parnafes (2007) focused on what Robin had said and her reference to the areas on the graph, and since both students were involved in this activity and seemed to be in agreement the analysis referred to both, even though Robin was the one who made the inferences: "Sue and Robin compared inferences from two settings: before, with smaller displacement, and now, with larger displacement. The distance between the "hills of the graph" was the same, but the peaks of the graph were higher in the current case" (p. 436). The information read from the graph and the inferences made were all considered to be shared by the students: "The students now had clear and stable perceptual foci that allowed them to detect the patterns in the simulation: the "skinniness" of the graph and its height" (p. 436). Furthermore, the short exchange between the students and the verification wasn't at all considered in this analysis. This interaction wasn't considered as consequential for the conceptual processes that were happening during this activity and was thus ignored.

What the analysis didn't do was to handle two active conceptual systems at the same time, with lived interaction between them. Many interactional moves were not analyzed and were considered transparent to the conceptual process of either the "system" or the two individuals. The interaction was "flattened", and what was brought into focus was one conceptual system (either of one actor, or a shared), and the processes that occurred within it. What happens outside that system was only considered as an input for the system.

Despite the limitations of these choices, the KA using CC theory produced some insightful and significant results about students' processes of developing understanding. The analysis offered a detailed description of students' critical steps in the development of conceptual understanding. The use of CC theory enabled me to track the development process of students' understanding with the simulations' representation. The detailed analysis resulted in a model describing four mechanisms that drive the development of understanding through the mediation of computer-based representations.

The results came out of the KA using CC theory could have been very difficult to produce, in the first place, with an integrative approach of paying equal attention to both knowledge and interaction. There are tradeoffs that we should be willing to consider in order to focus deeply on a particular aspect of interest. If we are aiming to produce a new theory on conceptual understanding, we may want to simplify the complexity introduced by interrelations to other aspects. Thus, "flattening" interaction enabled focusing deeply on individual conceptual understanding while compromising the depth of interaction and social context. However, integrative analysis may be conceived as being done in stages, where a later stage of analysis allows a richer analysis to eventually emerge that serves new purposes than the original analysis.

## A Coordination Class in Interaction

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Our work is grounded in the assumption that knowledge and interaction are fundamentally inseparable. This suggests that there is value in considering how interactional context influences the analysis of knowledge, and how an understanding of knowledge might in turn advance our considerations of interaction. Traditional approaches to knowledge analysis typically focus on social context and aspects of interaction to the extent that these aspects appear to be directly consequential for the analysis of conceptual structure and processes. In line with Parnafes' reflection on KA (this symposium), efforts are often made to account for the influence of an interlocutor on one individual's knowledge rather than treating a dyad as a combined unit that is co-constructing knowledge in interaction as many interaction analysts would assume. Interaction is not analyzed systematically and in any case doesn't play a central role in the attempt of understanding the learning situation. Therefore, in this paper our goal is to explore the implications for explicitly and intentionally combining knowledge analysis with interaction analysis in order to describe the process through which multiple participants may co-construct knowledge.

In direct contrast with the KA focus on knowledge over interaction, IA is designed to understand how people make sense of the social context that they are concurrently co-constructing with others. Knowledge is typically only viewed in terms of how it sheds light on the interaction. Thus, individual students' understanding is rarely explored in depth beyond its role in promoting interaction. Further, because IA takes a strong line towards avoiding analysis of anything beyond what is present in the current interaction (e.g., a focus on talk and gesture), this kind of knowledge is rarely explored in the way that KA does.

Our integrative analysis attempts to do both. We attempt to analyze the role of interaction in producing, shaping, and revealing students' knowledge, as well as how knowledge helps to structure, promote and necessitate new interactive components. Specifically, we attempt to complement Parnafes' (2007) prior KA by creating a synthesized account that we believe goes beyond what either KA or IA would accomplish individually. To support this effort we re-analyze the same episode as presented by Parnafes with the intention of explicitly introducing an IA and integrating it with the prior KA to show how the two can enhance each other. By contrasting this synthesized analysis with the prior analysis it also becomes possible to articulate how the one builds explicitly upon the other and to attend to the strengths and weaknesses of both approaches. Thus our paper also analyzes the episode of two students working together with a computer simulation to jointly develop and produce a way of reasoning and making inferences about the interrelations of speed, time and distance in the context of natural harmonic oscillation. We focus on small group work as a site for understanding the relationship between knowledge and interaction, as this kind of organization is both ubiquitous and assumed to support learning in a number of ways.

Several assumptions guide our attempts to do integrative analysis of KA and IA, and we use this specific case, already analyzed with a KA approach, to demonstrate the merits of such integration. First, we assume that individual learning is often influenced by interaction and collaboration with others. Second, we assume the shape or structure of what is learned will often reflect the nature of the interactions in which learning occurs. Third, there are potential benefits to well-organized collaborative learning that might make collaborative knowledge construction different and perhaps more flexible or robust than individual knowledge construction.

To help illustrate how the two approaches might be integrated, we conducted our analysis in three passes. First, we completed a strict KA that focused on the organization of the students' knowledge. Second, we completed a strict IA that focused on how the students were interacting and why. We refer to these analyses as "strict" because we attempted to avoid developing un-systematic and common-sense inferences about the aspect of the analysis that we were not focusing on. That is, we attempted to avoid casual analyses of interaction during our KA or knowledge in our IA pass. Finally, we attempted an integrative analysis that builds on both while aiming to explicitly identify the role of interaction in influencing students' knowledge and vice versa. To accomplish this we examine the sequential production of talk, identifying moments where the students construct intersubjectivity, or appear to lead to conclusion. As they achieve intersubjectivity, we then highlight the interactional elements necessary to help create this moment of shared attention and understanding.

For example, our case study episode begins with Robin noticing that two graphs have the same "skinniness" but one is higher than the other (the same segment presented by Parnafes, this symposium). From a KA perspective, we note how Robin therefore is noticing a representational discrepancy, and building on her understanding of graphs and of velocity to recognize that these features are both relevant and different, though she has not yet articulated why that might be the case. From an IA standpoint, we note how crucial gesture (using the mouse) is to this exchange, allowing Robin to help direct Sue's attention to key features of the graph, and allowing them to develop a shared sense of what they are discussing (intersubjectivity). Furthermore, simple descriptive phrases such as "skinniness" which are non-technical appear to help establish intersubjectivity. We also see Sue ratifying the sense that there is in fact a shared intersubjective understanding of the setting with simple phrases such as yeah and yes. Our integrative analysis then further suggests that this simple establishment of intersubjectivity is in fact made possible by some shared knowledge structures—that Sue's ability to read the same anomaly that Robin sees allows them to be on the same page, while the fact that they are actually on the same page (indicated later in the episode) helps to strengthen our belief that their knowledge structures are similar with regard to these concepts. This work to establish a shared understanding is then crucial to how the students make sense of the notion of speed in the remaining episodes, which we will describe in greater detail in our full paper.

While this is only a very brief example from the first line of interaction, it helps to illustrate our approach. In particular, we can begin to see here how the combined approach helps us to systematically identify the relationship between the interaction and interactional processes and the knowledge that is so crucial to this exchange. In the remainder of our analysis, we further indicate how the ongoing effort to maintain intersubjectivity within the social context of doing inquiry in a classroom helps to move the students' knowledge construction forward. At the same time, it is increasingly clear that without an evaluation of the students' knowledge, we could make little sense of some of the exchanges beyond saying simply "the students appear to agree on what this means." Given our interest in analyzing and designing educational environments, this approach therefore supports our efforts in better understanding how learning and knowing are supported through rich social contexts.

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## Acknowledgments

We gratefully acknowledge the American Educational Research Conferences Program for providing funding to host a conference on the theme of this symposium in Marin, California, June, 2011. This conference was organized by Mariana Levin, Orit Parnafes, and Andrea diSessa.

# **Reimagining Cultural Forms, Ethnographic Methods and Researcher Responsibilities in Studying Engineering and Science Learning: Honoring and Building on the Work of Margaret Eisenhart**

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**Abstract:** Honoring and building on the work of Margaret Eisenhart, this set of papers delimits the myriad ways that four studies have reimagined cultural forms, deployed ethnographic methods, and conceived of researcher ethical responsibilities in studying engineering and science learning. Framed by cultural production theory, critical intersectionality, actor network theory, and a sociocultural-historical stance, these studies illustrate the interconnected nature of learning and becoming processes, the complexity of cultural forms and engineer/scientific identity productions, and the continued salience of structural forces to shape learning and becoming in life-wide settings. Ethnographic methods served these studies well by providing access to time-dependent processes, by immersing the researchers in their field sites over time, and by allowing seeing from the inside out to privilege the perspectives of research participants. Each study found ways to follow individuals and structures simultaneously, and to document cultural forms and variations in the ways insiders took up cultural forms.

## **Overall Focus and Theme**

Sociological and anthropological inquiries into patterns of wealth, social mobility, and opportunity in society, and the role that schooling plays in perpetuating or disrupting these patterns are now decades old. All of us involved in this symposium are engaged in the question of how societal forces influence learning in the contexts of science and engineering. Reflecting the 2014 ICLS theme of *learning and becoming in practice*, we consider how the anthropology of education, and more specifically the scholarship of Margaret Eisenhart, offers important tools and insights for understanding and acting at this intersection of how people learn and how sociocultural forces influence that learning. Connell (1987) coined the term “practice theories” (as opposed to categorical theories) to highlight the ways in which structures that had been taken for granted in prior theories (e.g., social reproduction theory) should become questions for research. Similarly, Levinson, Foley, and Holland (1996) argued that practice theories afford a reconsideration of the permanence of social structures through a close examination of moment-to-moment social practices. By viewing structural categories as impermanent, practice theorists hope to more appropriately balance the disciplining power of social structures with the visible differences in how individuals, who seem to occupy the same structurally defined categories, actively make meaning of the world around them, and exert personal agency within and against those structures (Eisenhart & Finkel, 1998). As Eisenhart (2001) argued over a decade ago,

[E]veryday life, including life in schools, seems to be faster paced, more diverse, more complicated, more entangled than before. The kinds of personal and social relationships, exchanges, and networks we participate in seem to be taking new forms, tying together otherwise disparate people, and demanding some new ways of thinking about what to research and how to do it. (p. 24)

Despite these nuanced understandings of societal forces that are studied within the realm of educational scholarship, there has been renewed enthusiasm within the political and policy realm for viewing schooling as a microcosm of a meritocratic society, in which the smartest, hardest working, and most well behaved students will be rewarded with an education that can be parlayed into a socially and economically successful life (Hursh, 2005). While the argument that education serves as a meritocratic equalizer to socioeconomic disparities has been with us at least since the end of World War II (Themalidis, 2008), this neoliberal viewpoint has gained renewed favor in the justifications for our current academic accountability systems (O’Neill, 2013). Powerful tools and arguments are required to push back against this neoliberal tide that paints successful learning, as well as other successes in life, as individual accomplishments. Margaret Eisenhart’s work has provided us with some of those tools.

The set of papers in this symposium takes up Eisenhart’s challenge of exploring new ways of thinking about how to research structure and practice, culture and identity, within the context of how people learn science

and engineering. While building on Eisenhart's ideas in different ways and in different contexts, all of our work highlights the ongoing value of *attending to cultural forms, reinvigorating ethnographic methods*, and *reconsidering the ethical responsibilities of researchers* with an eye toward challenging neoliberal assumptions and promoting more equitable and meaningful science and engineering learning opportunities. We view our work as part of the interdisciplinary field of the learning sciences given our concerns for improving learning through designed educational settings, with a focus on human agency, values, motives, and goals central to the human sciences (Penuel & O'Connor, 2010).

## Cultural Production on an Engineering Campus: Learning, Power, and Engineer Identities

Karen L. Tonso

Though anthropologists understand culture to be something produced in everyday activities among a group with a shared life, culture as a concept shifted from being given, to being made, from reproductions (e.g., Connell, Ashenden, Kessler, & Dowsett, 1982), to more open productions (Levinson, et al., 1996; Willis, 1977).

Cultural forms provide the material towards, and the immediate context of, the construction of subjectivities and the confirmation of identity. It provides what were the most believable and rewarding accounts for the individual, his future and especially for the expression of his/her vital energies. (Willis, 1977, p. 173)

As such, individuals moved from *objects of* cultural processes to *actors in* cultural processes. Studies of high school life (e.g., Eckert, 1989; Foley, 1990; Willis, 1977) suggested the salience of schools to frame individuals' actions, to interpret those actions, and ultimately to elevate some ahead of others (Foucault, 1982), and to do so along well-worn societal structures – social class, gender, race/ethnicity – smuggled into life at school.

[I]dentities are improvised – in the flow of activity within specific social situations – from the cultural resources at hand. Thus persons and, to a lesser extent, groups are caught in the tensions between past histories that have settled in them and the present discourses and images that attract them or somehow impinge on them. (Holland et al., 1998, p. 4)

Beginning with a strand of research that fed into *Women's Science* (1998), I was open to possibilities for cultural change that might be allowed in a college setting incorporating out-of-school practices. Here I hoped to document to what extent "Individuals respond to the structural alternatives, and as they do, [if] they actively negotiate and sometimes contest the identities produced for them" (Eisenhart, 1996, p. 183). In many early conversations, Eisenhart asked: "What do people make of their world?" while I persistently wondered "And what does their world make of them?" Both questions proved crucial. Thus, in the early 1990s with hope for individual actions leading to cultural change, I took a cultural production stance, and followed how school practices and societal forces impinged on individuals' becoming members of a campus engineering culture while student engineers did real-world engineering projects for out-of-school clients. I found that engineer identity productions demonstrated learning processes, power relations, local culture, and societal constraints.

### Student Engineers Identities as Powered, Gendered, Cultural Form

Students displayed a wide range of ways to be engineers. In student design teams, terms referring to one another as different types of engineer emerged, and these proved a ready discourse (ala Foucault) for recognizing one another's expertise and for chastising unacceptable behavior. These engineer identity terms provided a rich cultural calculus for belonging, or when absent or silent on certain things, also marked not belonging (Tonso, 2006). Students' actions were given meaning using these terms, even as students actively hid behaviors to avoid being admonished by colleagues. Students organized terms into two larger categories: Over-Achievers and Nerds. Clearly, Over-Achievers ruled, since campus elevated them via culturally salient recognition routines. Some among Over-Achievers deployed their power to the detriment of others. For example, an extraordinarily hard-working student might arrive for a meeting just on time and have a higher status teammate miscast him as a slacker (lazy, worthless teammate). Within the categories, only six terms (out of the 36 most-prevalent terms) referred to women. Most were pejorative, except for "sorority woman," which most women student engineers rejected. The absence of terms for women (in the portions of the identity terrain that marked being engineers) made women invisible as engineers. Over time as students learned how to be engineers on campus, some students asserted themselves using the terms, and others actively hid some aspects of their selves to avoid being hassled. But being a woman proved impossible to hide, making women student engineers hypervisible as women. Ultimately, student social interactions helped produce cultural forms made evident in the identity

terrain, even as extant cultural forms framed insider actions. The campus exemplified a culture filled with tensions about being engineers and doing engineering. In addition, this research highlights cultural production processes which depend on the simultaneity dance between cultural forms and individuals, the give and take of a shaping-and-being-shaped-by process, which I argue proves central to understanding learning in sociocultural contexts. As Eisenhart later wrote: “we can no longer conceive of social groups of people with a culture that is clearly bounded and determined, internally coherent, and uniformly meaningful” (Eisenhart, 2001, p. 17).

### **Methods that Reinvigorated Studying Cultural Forms**

Two strategies used in this study augmented classic ethnographic methods of participant-observation fieldnotes, ethnographic interview, and artifact analysis of student reports and oral presentations (Spradley, 1980). First a paired set of interview questions unpacked the identity terrain. Using a queue-sort strategy (Holland & Skinner, 1987), I initially asked students to list, then define or describe terms they used to refer to one another as engineers, then in a subsequent interview asked them to sort the most prevalent terms into categories that made sense to them and to explain their sorting. Second, coupling this approach with quasi-longitudinal fieldwork of first-, second-, and fourth-year courses (but different students in each course) provided the time dimension central to understanding learning as a process. First-year students knew little about the terms, second-semester sophomores used the terms sparsely, and seniors had a deep understanding, illustrating how student engineers’ expertise extended well beyond the intended curriculum and was learned over time.

### **Rethinking the Ethical Responsibilities of Researchers**

Two issues framed my interpretations of my ethical responsibilities, especially to document variety, conflict, and tension among participants. First, I had been struck by the extent to which researchers, especially in STEM sites of practice, did not comment on gendered findings (Downey, 1993; Nespor, 1994), while others focused on them (Foley, 1990; Hacker, 1989; Holland & Eisenhart, 1990; Traweek, 1988). I endeavored to see genders in all humans, women and men, and to interrogate the diversities of femininities and masculinities, instead of using gender as a demographic binary. Late in the research, one set of interview questions provided a serendipitously rich set of responses. First I asked: “What is it like to be a man here?” and followed with “Would it be different if you were a woman?” Later in the interview, I engaged in a conversation about equality and what it meant on this campus. Responding to the first two questions, students provided a large collection of stories about inequitable circumstances, but later told me “we’re all equal engineers.” Unearthing this illogic illustrated the power of cultural forms to create in the mind’s eye the imagined cultural situation – equality – in spite of considerable empirical evidence to the contrary. Second, I began the research with reservations about research conducted either by social scientists lacking engineering credentials or by engineering educators who lacked social science capabilities. Having worked for 15 years as an engineer allowed me not only to follow students’ engineering talk but also to evaluate it, while my anthropological training helped me investigate how things came to be the way they were, instead of focusing overmuch on only seeing what they were.

## **How Actor Network Theory Can Challenge the Assemblages of School Accountability and Science Learning**

Cory Buxton

A central facet of the Language-Rich Inquiry Science with English Language Learners (LISELL) project is the LISELL professional learning framework. The five components of this framework offer opportunities for participants (teachers, students, parents, and researchers) to position themselves in different ways for varying purposes in distinctive spaces. Among other questions, we have explored how varied identities for learning are made possible for participants based on how they choose to position themselves and how they are positioned by others (i.e., school administrators, other participants, project materials) in the multiple spaces of our work together. We wonder how participants may gain new insights about themselves and about others based on this variable positioning and the identities afforded across these spaces. At the same time, possible identities are constrained by components of the broader networks in which the LISELL professional learning framework is embedded, such as one’s immigration status and English language proficiency. While our full model considers the positioning of teachers, researchers, students and family members, for the purpose of this paper we limit our consideration to the roles that teachers and researchers play across the five components of the professional learning framework, while attending to Eisenhart’s notions of reconceptualized cultural forms.

In the Teacher Professional Learning Institute, the teachers’ initial positioning is as critical evaluators of the LISELL pedagogical model and then as co-developers of classroom content and practices, while the researchers’ initial positioning is as advocates for the pedagogical model and then as co-developers of classroom content and practices. In the Student Biotechnology Academy, the teachers are positioned both as instructors and as Spanish language learners, while the researchers are positioned as facilitators and participant observers. In the professional learning spaces of Grand Rounds classroom observations, the teachers are positioned as

collaborators observing their peers and being observed in turn, while the researchers are positioned as co-observers, learning how project practices are enacted in classrooms. In the Steps to College through Science Bilingual Family Workshops the teachers are positioned as participant observers, Spanish language learners and advocates for their students, while the researchers are positioned as teachers, facilitators, and learners across both organized and impromptu learning experiences. Finally, in the LISELL assessment workshops, teachers are positioned as assessment experts and reflective practitioners, while the researchers are positioned as assessment trainers and as facilitators of reflections on learning from student writing.

### **Attending to Cultural Forms**

Heeding Eisenhart's (2001) call that new ways of thinking may be needed to better understand the diverse entanglements of life in schools without abandoning the notion of culture, the LISELL project has been using Actor Network Theory (or ANT) to identify the resources that are mobilized to establish (or assemble) our professional learning framework (Law, 2004). We view ANT as a powerful bridge between anthropological thinking about culture and the practices of design that may directly influence learning (Latour, 2008). While not a new theory (Callon & Latour, 1981), ANT has remained obscure in educational research (Fenwick & Edwards, 2013). By insisting on the principle of *symmetry* – that human actors and influences should not be privileged over non-human actors such as devices, documents, or spaces – ANT provides a novel lens for understanding how social forces (including knowledge) gather allies (and enemies) to become more and more (or less and less) stable over time (Callon, 1986). This process – *translation* in ANT terminology – can be used to explain how the growth and shrinking, the stabilizing and destabilizing of networks, shape the ways in which social organizations function (e.g., how our professional learning framework, co-constructed by researchers, teachers and other participants, become stabilized and mobilized in some spaces but not in others). Following an ANTish view of how practices are shaped, we looked for *obligatory passage points* (key points through which actors must pass once a network has been stabilized), such as teachers being observed by their peers during grand rounds observations or researchers having their materials critiqued by teachers during the teacher institute. We also attended to *stable mobiles* (elements of a network that stabilized to the point that they can be lifted out of one context and moved to another and still function with the same meaning), such as classroom materials for supporting English learners that are developed by teachers in our project spaces and then taken up by teachers in other schools). When taken together, these ANT concepts provide a different way of examining the moment-to-moment social practices in our LISELL professional learning interactions, as well as the relationships between the disciplining power of social structures such as a school accountability system and the individual and collective agency shaped by LISELL project participation. For example, we have explored how the stable mobile of a superintendent's *non-negotiable practices for instruction* became hybridized with the LISELL pedagogical model to destabilize certain classroom practices that hindered the science learning of ELL students (Buxton, Kayumova & Allexsaht-Snider, 2013).

### **Reinvigorating Ethnographic Methods**

ANT may provide a way to reinvigorate ethnographic methods with its attention – via symmetry – to a range of resources that include people, devices, decisions, documents, organizations, and the connections between all of these. As Eisenhart (2001) noted,

If we are going to trace relationships that stretch out across time and space; and if we are going to analyze activities and cultural forms that are taken up locally but formed or controlled elsewhere, we would seem to need some new ways of doing ethnography, or at least some different methodological priorities. (22).

Thus, in the LISELL project, we held true to certain fundamental principles of ethnography (e.g., participant observation and researcher journaling) while also exploring new approaches to data collection and analysis. For example, by purposefully constructing the five distinct settings and interaction styles in our professional learning framework and inviting different sets of participants from across multiple schools and community contexts into these settings, we have been able to study how the same individuals practice science learning身份 situationally. Further, by developing an ANT sensibility toward symmetry, we have traced relationships that involve not only people but non-human actors as well. For example, we were able to consider how the various settings of the professional learning framework influenced the ways that English and Spanish, as well as everyday and academic language, were used as tools to support science learning. Thus, the prominence of Spanish and Spanish-English fusions in the Steps to College family workshops caused teachers to engage differently in the learning process, for example, by listening more and talking less.

### **Rethinking the Ethical Responsibilities of Researchers**

Finally, in the LISELL project we have taken up Eisenhart's challenge that researchers be ethically responsible for painting a balanced and respectful picture of what and whom we study and to grapple with what it means to

create positive change when actors hold divergent ideas in complex contexts. For example, our diverse 9-person research team represents 6 countries of birth and speaks a total of 10 different languages, positioning us quite well to be both alert and sensitive to the implications of cultural and linguistic differences, as well as how those differences influence learning opportunities across the contexts of our professional learning framework. We have tried to balance the voices of various stakeholders (families, students, teachers and researchers) as we think, talk, and sometimes argue together about what makes science learning authentic and worthwhile and how such learning can be fostered for all students within the current accountability structures in our schools. For example, we have had lengthy discussions about the value of outstanding academic achievement if undocumented students are prohibited from attending selective institutions of higher education.

## **Possibility of Multiplicity: A Spatial Analysis of an Afterschool Participatory Science Media Project as Lived by Youth, Student Teachers, Community Organizations and Researchers**

Jrene Rahm

“What are the images that are useful for researchers to “think with” in the contemporary world? Will the images we have relied on for years work or do we need new ones?” (p. 16), a question Margaret Eisenhart (2001) asked over a decade ago and that we build on in this paper. We are reporting on an action research project that entails partnerships among a University and its teacher education program, community organizations, and high schools. That is, we look inside two different afterschool media-science clubs that we ran for two academic school years in partnership with two secondary schools in Montreal, science organizations like the Botanical Garden (summer internship for youth participants), and the University of Montreal (student internships in clubs), inspired by the Fifth Dimension Model (Cole, 2006). Theoretically grounded in sociocultural historical research, each afterschool club is understood as a complex activity system, embedded in a network of culturally heterogeneous activities that are in continuous transformation and movement (Engeström et al., 1999; Sannino et al., 2010). As advocated by the Connected Learning Research Network report (Ito et al., 2013), youth were offered opportunities to pursue media projects on scientific questions and topics they deemed meaningful, under guidance of caring adults and other youth, and as such, supportive of engagement, self-expression and youth voice. The study also responds to issues raised recently in the National Academies Press report, “A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas” (2012), and its emphasis on promoting scientific literacy *for all*, with science literacy being “a democratic ideal worthy of focused attention, significant resources, and continuing effort” (p. 277). In many ways, the project we describe can be seen as “a significant resource” we put in place in two high schools to complement school learning for youth and student teachers, a project driven by high academic goals and standards for all participants and partner organizations.

Two years into the project, however, it became clear that new lenses were needed to “think with” to understand what is happening within each partnership and established system. As Eisenhart contends, we were “pushed by theoretical and social currents to trace cultural forms ‘upward’ and ‘outward’ so as to consider how they are manifested and produced in networks of larger systems.” Yet, simultaneously, we were also “pushed ‘downward’ and ‘inward’ to see how cultural forms become part of individual subjectivities or imaginations” (p. 22). It made us build upon ideas central to multi-sited ethnography in that we grounded our understandings of cultural forms in space-time configurations and a “posited logic of association or connection among sites” (Marcus, 1998, p. 90), both imagined and lived or brought alive *in situ*. Moving inwards helped us first posit a certain design of the clubs while making possible the study of their transformation within each complex system over time. That is, the science clubs were grounded in research on youths’ participatory cultures (Jenkins et al., 2009), and designed to build upon youths’ cultural on-line practices of creative media productions, pursued through collaborative problem solving or the posting on blogs and podcasts. By situating the imaginary in the literature on new media culture, a youth participatory framing and making of the clubs was possible. At the same time, it left us to wonder about whether our designing for learning worked, and if so, for whom?

Next to methodology, we also needed to mobilize different conceptual tools to understand what was happening and the significance it might have for different learners. We mobilized theories of spatiality which helped us focus on the premise that “how a space is seen, experienced, and understood depends on the positionality of people relative to the space” and their position within society and history (Moje, 2004, p. 15). Accordingly, we could explore in what ways the club was experienced and perceived by our student teachers and how that differed from the manner the researchers, instructors and youth lived the clubs, which in each case was tangled up in complex ways with the larger relational logic of its place. For instance, our student teachers were caught off guard by the orderliness of the club despite its location in an underserved community. They were recognized and positioned as outsiders by the youth in the club, who referred to them as strange. As a consequence, the research and researchers became mediators of worlds, smoothing out a complex interplay of positioning grounded in different spatial histories and current ways of life among student teachers, and youth. The project and its transformation over time also challenged the ethical responsibilities of us as researchers. For

instance, it led us to focus on the sustainability of the clubs over time, beyond the three year funding cycle of the project, a challenge many Fifth Dimension projects have struggled with in the past (Cole, 2006). It also led us to re-envision the project as a dialogical one (Matusoy, 2011). We not only promoted dialogue among different members of the partnerships, but made an effort to continuously explore and focus on multiple voices at stake in the project, those of youth, animators, student teachers, researchers and professionals from the many partnering institutions. It led to a new research imaginary marked by contradictions and complexity, yet making possible an imaginary of the possibilities of multiplicity in terms of learning, identity work and space-time trajectories. In sum, the paper offers one story of an attempt to think in new ways “about what to research and how to do it” (p. 24) that Margaret Eisenhart called for a decade ago.

## **Learning Science at the Intersections of Race, Class, and Gender: A Longitudinal Study of Girls Negotiating What it Means to “Be Scientific”**

Heidi Carbone and Angela Johnson

Historically, pre-adolescent girls’ science learning is framed in multiple ways, including but not limited to: an achievement gap problem; a problem with deficit knowledge and skills; girls’ lack of interest and/or “science identities”; school science’s lack of relevance to girls’ interests, goals, and funds of knowledge; lack of role models and mentors. Many of these framings are consistent with neoliberal, meritocratic views of school, science and learning. They are based on the assumption that addressing the problem will make for a better, more equitable, school science. Yet, we argue that the existing framings of the problem may *not* be the problems girls care about solving, that cause them struggle, or that are integral aspects of their identity work.

### **Attending to Cultural Forms**

Eisenhart (2001) argued about the limitations of the traditional ethnographic strategy of conceptualizing the school or classroom’s culture as a “fairly stable adaptation to the external forces impinging on it” (p. 24), which leaves unexamined the ways external forces get produced in everyday practices, and the ways the classroom can be considered as “a point of entry...to the study of economic, cultural, and political relations shaping the curriculum, teaching, and kids’ experiences” (Eisenhart, 2001, p. 24; citing Nespor, 1997, p. xiii). Following Eisenhart, we study science learning settings, not only for what they teach us about science but, more importantly, for what they teach us about inequity and how power is produced and reproduced.

The study we report on here brought this point front and center. Our original goal was to study the science identity work of ethnically, racially, socioeconomically, and linguistically diverse students across three to four years of school science after experiencing one year of excellent fourth- or fifth-grade science teaching. However, when we focused on identity work practiced by the girls in the study ( $n=13$ ), entangled in complicated lives in school, the problem that concerned them was how to be a girl in science, with the emphasis on *girl* rather than on *science*. Their identity work in school science was focused on figuring out what kind of girl to be, not on being scientific. Our specific *research questions* are: Within and across four years of school science: (1) What is the nature of girls’ identity work? (2) What femininity practices do they make use of in their identity work? (3) How do these versions of femininity intersect with race and class? (4) How do the girls’ cultural practices impact their identity work as science learners?

### **Reinvigorating ethnographic methods**

This study draws, in part, on classic, ethnographic methods of observation, interview, and artifact collection—what girls did, said, and produced (Spradley, 1980) in school science over three to four years. As Eisenhart (2001) argued, “To be involved directly in the activities of people still seems to be the best method we have for learning about the meaning of things to the people we hope to understand... conventional ethnography, it turns out, is still a good methodological choice in many situations” (p. 25).

We did just that—carefully observing, talking to, and learning from girls over time in their school science settings, with home visits, lunch talks, and observations in other school settings during our final year of data collection. These kind of longitudinal, ethnographic data of students’ science learning and participation over time, though representative of “classic ethnography,” remains rare in the learning sciences literature.

Trained by Eisenhart to study classrooms ethnographically, to examine patterns of activity that give rise to *shared meanings across groups*, we found it a methodological challenge to focus on *individuals’* identity trajectories across time. Further, though we looked for ways individuals creatively leveraged resources from various cultural worlds to craft more satisfying identities for themselves, macro-level structures of race, class, and gender loomed large in each girl’s trajectory and became *more* prominent and relevant over time. So, we used multiracial feminist theory and intersectionality (Archer, et al., 2012; Collins, 2000; Johnson, Brown, Carbone, & Cuevas, 2011; Morris, 2007) as prominent study lenses. Doing so allowed us to consider how race, class, and gender combine in a matrix of oppression (Collins, 2000) and shaped girls’ science educations and identity work, creating “unique obstacles” (Morris, 2007) for those located deeper within the matrix of

oppression. A central assumption of this lens is that race, class, and gender are examined, in combination, as *performances* rather than *traits*: African American girls “practice,” rather than “have” Black femininity. These practices, patterned over time into cultural forms, make an “acceptable” racial class-based, and gendered, identity appear to be “fixed” and/or “natural” (Archer, et al., 2012; Butler, 1990). Identity work, as intersected with larger social structures, is particularly relevant in settings of power, like science. We focused in on girls’ performances of femininity, which allowed us to represent “diversity as well as commonality” of girls’ meaning making and identity work in school science (Eisenhart, 2001, pp. 24-25).

## **Findings**

In fourth grade, most girls made regular bids to be recognized for scientific and/or academic performances; all were “pleasers.” However, girls of color engaged in more identity work to be a “girl in science” in settings with narrower meanings of “science person.” In those settings, girls took up other, more interesting and accessible roles. Nearly all girls were encouraged to “speak up” except: (1) Two confident African American girls from working class backgrounds: One was positioned as a leader who needed to learn to share (Aliyah); the other was positioned as a “loud Black girl” (N’Lisha) (Fordham, 1993); (2) An English language learner from a working class background (Celeste) encountered obstacles in authoring a “competent” science identity in a classroom with narrow definitions of “success.”

By sixth and seventh grade, “nurturing” and “standing up for others” became subversive, not celebrated, practices—especially true of girls of color from poverty/working class backgrounds. Belonging, or minimizing “otherness,” became more prominent across time for nearly all girls. More girls performed as submissive or invisible by 7<sup>th</sup> grade; most were Latina girls from poverty, or working class backgrounds. “Pleasing adults” was consistent across time for most; but, over time, some girls of color unevenly performed as “resistant” or “rebellious.” Bids for leadership or dominance, though rare in 4<sup>th</sup> grade, became even rarer in 7<sup>th</sup> grade. All girls, except for Yazmin and Luisa (two, very academically strong Latina girls from working class backgrounds) changed their practices based on classroom norms.

## **Discussion**

Girls did not need to, nor did most want to, engage in “scientific identity work” to be successful in school science. By 7<sup>th</sup> grade, they were not asked to be particularly “scientific.” In the few instances when asked to be scientific, most did so with little struggle or resistance, suggesting that they had “learned” school science, though without perhaps learning to be scientific. We wonder: Have many of them (all “good students”) solved the “school science” problem?

All but two working class Latinas changed their practices based on classroom norms. We wonder: If the norms were altered to hold students accountable to more robust science practices, would their gendered/raced/classed-based identity work become less prominent? Would they learn more science? We have some indication that this may be true for two of the White girls who experienced robust school science in sixth grade. We do not know if this would be true of the girls of color because they did not generally experience robust school science in 6<sup>th</sup> or 7<sup>th</sup> grades.

African American girls from working class/poverty backgrounds were more likely to perform anti-hegemonic, “stronger” feminine roles (leadership, standing up for others). We attribute this to a resource called *la facultad*, the ability to read a social situation and respond accordingly (Anzaldúa, 1999; Johnson et al., 2011). This is a precarious resource. In sum, our study engaged us in the “‘work of ordering’ the forms of social life of which [our] research activity” became an integral part (Penuel & O’Connor, 2010, p. 280). This process became an “entry-point” (to pick up on Eisenhart’s earlier quote) to a complex web of interconnections, leaving us much to still disentangle.

## **Significance of Collective Work, Lessons Learned, and Moving Forward**

Grounded in widely different K-16 science and engineering learning settings, these ethnographic studies – of the ways in which cultural forms impinge on, and are produced through, social interactions in everyday life – illustrate how nuanced analysis can better shape equity-driven educational processes. Tonso’s engineering students learned to view their world through campus-culture-tinted lenses and to overlook contradictory empirical evidence. Their cultural identity terrain was framed by both campus culture and societal structures, and implied cultural knowledge about power, positioning, and belonging as an engineer. Buxton foregrounds how non-human actors, such as policy documents and lab materials in schools, can be central to the ways cultural forms are practiced and how networks where cultural forms are enacted are continuously being stabilized and destabilized. Rahm’s work in high school settings traced the paths of cultural forms simultaneously moving outward toward broader networks and inward to understand the making of individual identities. Carbone and Johnson’s study illustrated how students’ identity work fit into cultural practices, which were permeated with societal structures, especially gender, race/ethnicity, and social class. Both Tonso’s and Carbone and Johnson’s research studies illustrate how the situations within which identities form in some

learning settings can seem unable to support identities that simultaneously link scientific ways of being with femininities, even as these researchers make evident that much of what students learn falls outside the intended curriculum of the sites, raising prickly questions about studies that assume narrow conceptions of “curriculum.” In contrast, the studies by Buxton and Rahm offer illustrations of how complex the unpacking of everyday practices can be when attempting to design contexts for science learning that attend to multiple and conflicting interwoven discourses and practices (Latour, 2008). Taken together these studies demonstrate that life in these learning settings is both complex and constrained by cultural possibilities that are all too often overlooked in studies of learning; cultural possibilities that essentially constitute the kind of reframing of learning research currently being called for by the learning sciences.

In all four studies, learning was seen as a *process* that played out over time, that encompassed far more than the intended curriculum in the sites studied, and that embodied a wide range of cultural forms and structural forces at play in learning settings. All of these studies have implications for designing learning environments in ways that take equity and inclusion seriously. Buxton, Carbone and Johnson, and Tonso suggest the need to continue to study structural forces to enhance the potential for providing all students with equitable learning opportunities. Carbone and Johnson, and Tonso found that learning settings do not always recognize all who demonstrate capabilities considered important in learning settings, suggesting the limitations of studying persons extracted from context. Rahm and Buxton called for taking youth’s perspectives into account in designing learning settings that matter. These studies also make explicit that learning and becoming are inextricably interconnected, and that cultural forms not only shape learning possibilities, but are tied to the agency of learners and researchers (O’Connor & Penuel, 2010).

Taking an ethnographic approach contributes to research in the learning sciences in a variety of ways. As Tonso suggests, ethnography allows augmenting data-collection and analysis strategies to unearth implicit cultural forms, such as the queue-sort strategy used for unpacking the identity terrain. Ethnography also allows incorporating both spaces (Buxton, Rahm) and non-human actors (Buxton), and the influences of both on identity formation and learning. Because of its commitment to prolonged engagement and persistent observation (Lincoln & Guba, 1985), ethnography makes possible longitudinal and quasi-longitudinal research activities that trace students’ shifting identity work and learning (Carbone & Johnson, Tonso), and provides important complements to current longitudinal studies of cognitive change. Ethnographic researchers may study contexts that are extant (Tonso, Carbone & Johnson) but through interaction with participants in those contexts, may create a positive influence. Ethnographic researchers may also study settings in which they have intentionally positioned participant groups and organized spaces (Buxton, Rahm), to facilitate more (inter)active and participatory ethnographic methods. In either case, these methods may be conducive to research in the learning sciences. The studies clearly speak to the call of “organizing for learning” locally and globally, and as such, entail research that takes us places not always comfortable but that are constitutive of the kind of research that may in turn lead to transformation and action (O’Connor & Allen, 2010).

Finally, all four studies illustrate the importance of considering the ethical responsibilities of researchers in ways that may be informative to the field of the learning sciences. Each of us made a conscious decision to understand the world of our participants from the insiders’ vantage point, often privileging the meaning making of the researched over that of the researcher. Taking diverse voices and perspectives seriously proves essential to creating equitable learning settings. Buxton created intentional spaces for different groups of stakeholders, including often silenced groups such as undocumented parents, to ensure hearing each group’s concerns and needs related to learning and academic success. Carbone and Johnson focused on the identity work done by students and the ways in which some student identities became marginalized and silenced over time, which highlights the responsibilities researchers have to understand learners’ motivations which is yet another critical piece for learning scientists. Rahm illustrates how working dialogically across participant groups, and continuing beyond the limits of funding cycles, can serve to promote life-long learning while also addressing the ethical commitments we struggle with and yet must live up to as researchers. Tonso’s work suggests that making gender (and other circumstances) of all participants visible, and of matching researcher expertise to topics of study, are fundamental to organizing ethical research not only because such research takes all participants (groups) seriously, but also because it makes relevant how all people learn.

Each of us began our research careers under the guidance of Margaret Eisenhart, yet, over time, our research diverged in novel ways in response to central themes taken up in Margaret’s scholarship. As our studies suggest, we have each traveled into arenas that allowed us to develop new lines of thought. Whether complicating notions of engineer identity in ways not foreshadowed in “scientist” identity research (Tonso), layering race/ethnicity and social class with gender (Carbone & Johnson), thinking deeply about how to include a “significant resource” in an after-school program (Rahm), or studying actor networks as a practice of design in a multi-site ethnography (Buxton), each of these studies explicitly responded to challenges articulated by Eisenhart. Because it has been enormously generative for our research, and that of others who similarly owe their impetus to Eisenhart’s scholarship, we honor her work. As a body, this research suggests that the depth of Margaret Eisenhart’s contribution to the learning sciences extends to theorizing, methodological strategies, and

empirical results that provide a unique vantage point on how people learn and become, in science and engineering settings, and beyond.

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# When Friends Argue: Investigating Argumentative Learning Processes in Facebook

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**Abstract:** This symposium addresses how argumentation can be leveraged for learning in social media like Facebook (FB) exemplifying social learning. It catalyzes an international discussion forum (Germany, Israel, United States) that seeks to understand argumentative processes beyond isolated technology-based learning environments, what influences them, if and how they can be repurposed for learning. We aim to contribute to the longstanding interest in argumentative learning in the learning sciences and extend knowledge about analyzing and supporting argumentation processes in FB. We examine the conditions under which FB can be harnessed for argumentative learning. We measure declarative knowledge outcomes and explore the development of attitude and civic behavior. Synthesizing across the papers, we will pinpoint the affordances of FB for argumentative learning, comparing processes to standard learning science approaches and exploring new socially embedded learning outcomes. We will frame promising directions for further research work.

## Introduction

Online social network sites (SNSs) like Facebook (FB), are the dominant technology-mediated leisure activity among teenagers in different countries (Rideout, Foehr, Roberts, 2010; Geocartography Group, 2011) and can be seen as exemplifying social learning (Bingham, & Conner, 2010). Online SNSs are defined by the following socio-technical features: 1) uniquely identifiable profiles that consist of user-supplied content and/or system-provided data; 2) (semi-) public display of connections that can be traversed by others; and 3) features that allow users to consume, produce, and/or interact with user-generated content provided by their connections on the site (Ellison & Boyd, 2013, p. 7). As FB is an integral part of high school and college students' routines, learning applications that exploit these routines may help students bridge formal and informal learning by situating social learning opportunities within their everyday social contexts and appropriating peer interactions on both curricular and extra-curricular topics. As such, FB is attracting interest from educators and learning scientists as a potential platform for online learning (Greenhow & Li, 2013; Greenhow, Menzer & Gibbins, 2012).

However, conceptualizing FB as a learning platform, and designing FB applications for learning pose challenges. Researchers have warned against exploiting FB for learning based on postulations about students' multitasking ability (e.g., Junco & Cotton, 2013). Similarly, Kirschner & Karpinski (2010) found a negative influence of time spent on FB and college grades. On the other hand, recent research suggests that *how* FB is used makes a difference in whether academic outcomes are positive or negative (e.g., Junco, 2012). For example, posting status updates and chatting on FB were negatively predictive of GPA, while checking status updates and sharing links were positively predictive (Junco, 2012). Interacting with fellow students around curricular content or other learning-related topics may be expected to be positively associated with achievement, but also with conceptions of learning as becoming part of a practice- or interest-driven community.

In this symposium, we focus on a particular type of learning in FB: learning from peer argumentation (Andriessen, 2006) that has been of longstanding interest to learning scientists. Learning from argumentation has been extensively studied in face-to-face settings (e.g., Herrenkohl & Cornelius, 2013) and in online discussion platforms specifically designed for educational purposes (e.g., Digalo, Belvedere, LASAD, ARGUNAUT, LARGO; Scheuer, Loll, Pinkwart, & McLaren, 2010). However, it has proven difficult to exploit its theoretical potential in already time-strapped classrooms (Sadler, Barab & Scott, 2012) or in formal, course-related e-discussions. As we consider the rich contexts of activity within which people today can create learning opportunities (Barron, 2006), peer groups embedded in social network sites like FB reside outside or are satellites of formal education, and therefore hold promise for facilitating argumentative learning processes — when Friends argue. However, to our best understanding this aspect of argumentation and of SNSs has not been studied yet. The goal of this symposium is, then, to present and synthesize recent research on argumentation and learning from argumentation in Facebook. It synthesizes a set of papers that offer a methodological balance between external and internal validity and either isolate and scrutinize specific characteristics of FB that are

theoretically relevant to argumentative learning in controlled studies, or investigate argumentation in long-term quasi experimental studies, or explore the potential of real FB situations for argumentative learning.

The papers in this symposium focus on various aspects of typical FB interactions like passive vs active argumentative processes, spontaneous vs. solicited participation, private (observing) vs. public communication formats. They study how such interactions affect argumentation processes, learning through argumentation, and how they contribute to learning as personality development. They define instructional support that leverages ‘native’ social and dialogic FB processes, inspired by existing learning science models, e.g. vicarious learning, group awareness support, and scripting argumentative knowledge construction (Contributions 1, 2 and 4). They investigate how vicarious observing as a common form of passive participation in FB discussions may lead to individual learning and how this learning is, in turn, influenced by rhetoric. They investigate the effects of group awareness support (e.g. the awareness that peers read and critically assess posts) as a main affordance of FB, how this affordance interacts with argumentation scripts, and if FB affordances are compatible with such support (Contributions 2 and 4). They explore how knowledge co-construction and epistemic communication may occur among FB-using youth and form civic behavior (Contribution 3). They investigate how argumentation and social aspects of communication influence declarative and argumentative learning outcomes (Contributions 1-4), but also how they relate to civic engagement and communication competence (Contributions 3 and 4).

Together, the four papers suggest that FB with its social character and broad use offers a unique arena for learning sciences research. Insights on leveraging FB for learning show great potential, but also possible pitfalls. The papers suggest that to describe a framework for using FB as a learning platform, unproductive aspects of FB need to be identified and counterbalanced, and new structures, designed educational features or social supports need to be introduced. For example, disputative argumentative discussions may increase initial interest and draw readers into argumentation processes, but they reduce learning effects in comparison to deliberative argumentative discussions. Group awareness support may engage learners and make them aware of their social context (e.g., that others will interact with their work), but it may induce over-cautious argumentative behavior that hinders learning. Individual preparation may reduce process losses related to the extra overload of simultaneously deliberating on individual arguments and arguing collaborative, but may also reduce knowledge co-construction. Adolescent FB users may perceive FB as more conducive to enacting civic behaviors than they do other online forums, but neither conflict-oriented nor quick consensus building in argumentation around key issues correlates with increases in civic participation. FB discussions may foster learning especially if additional group awareness is supported, in which case communication attitude change correlates with learning.

The contributions in this symposium identify the affordances and tensions mentioned above, helping the field to advance toward understanding argumentative learning processes in a range of contexts. The rich context of FB may host and even accelerate socio-cognitive processes, allowing researchers to log, trace and examine them for the first time, thus offering a breakthrough in scrutinizing influential social learning theories, such as social constructivism (Vygotsky, 1978) and communities of learning (Wenger, Richard McDermott & Snyder, 2002). For example, what are the social aspects that influence learning (e.g. rhetoric style, group awareness, communication competence and attitude)? How do cognitive and social forms of learning interact (e.g. declarative learning gains and communication attitude, argumentative knowledge and civic behavior)? What instructional design can promote this interaction (e.g. deliberative discussions, argumentation support)? As such, the research featured lies at the heart of learning and becoming in practice. Furthermore, given the role of FB and other social media in recent political developments worldwide, understanding such processes might facilitate our own learning to deliberate in these spaces and becoming more engaged learning scientist-citizens.

## Symposium Format

An introduction like the first part of the proposal will present the importance of the topic. Then individual papers will raise their central points and controversies, while findings will be used to ground the discussion in empirical results. One aim will be to critically consider and synthesize the different perspectives of the papers, including the generalization of the results and the methods. The discussant, Douglas Clark, will moderate the discussion. Douglas Clark is a leading researcher in the field of collaborative argumentative learning and a developer of new analysis methods of argumentation suitable for online asynchronous discussions. He is, therefore, aptly suited to help us critically assess the value, implications of the work presented to the field, enrich the methods used, and sketch a framework for pursuing the research questions further. The results of the symposium will set a precedent for interested researchers and will help them situate their own research into the proposed framework.

## Learning from Reading SNS Group Discussions: Rhetoric Style Matters

Christa S. C. Asterhan, Rakheli Hever and Baruch B. Schwarz, Hebrew University of Jerusalem

While browsing and clicking through the activities of one's FB contacts, FB users are exposed to various types of discussions on a variety of topics, as well as external materials linked from those discussions (e.g., articles, images, multimedia), often including heated discussions on issues of the hour. It would seem that FB as a social

arena is a hotbed of discussion, usually between FB "friends" but also with relative strangers who happen to subscribe to the same group or page, or to read the same article using the FB social plug-in. There is much to be learned from such discussions, even by people who are not themselves contributing posts to the discussion. However, this potential is currently not exploited in educational settings, and, compared to normative models of productive argumentation for learning (e.g., Asterhan, 2013; Keefer et al., 2000), the quality of these discussions may often prove to be sub-optimal. We then focus on whether and how individuals may learn from vicariously observing (that is: reading) online group discussions on a hot topic. Recent research by Wise, Speer, Marbouti and Hsiao (2013) shows that this online 'listening' is indeed a substantial component of students' participation in online course discussions, averaging about 75% of their time across students. The question is whether this also results in learning? Previous studies have reported positive correlations between the number of discussion posts students access and their course achievement (e.g., Morris et al, 2005). However, individual differences (e.g., in prior knowledge, interest and motivation) may account for the covariance between the two variables and a more experimental approach is then called for.

In this presentation, we report on a study investigating the effect of reading a FB discussion with links to external information resources, by comparing it to a control condition in which students only received the online resources. In addition, we investigate the effect of different rhetoric styles in argumentative discourse. Recent experimental research on active participation in computer-mediated argumentative discourse (e.g., Astarhan & Babichenko, 2013) has demonstrated that deliberative argumentation (a focus on critically exploring different viewpoints) leads to superior individual learning gains, compared to disputative argumentation (a focus on undermining the opponents' claims and winning the debate). Taking this a step further, it is expected that rhetoric style would affect learning from *reading* an online discussion. However, expectations regarding effects of reading a disputative *vs.* a deliberative discussion on learning are less straightforward: On the one hand, reading a disputative discussion could lead to higher arousal and increase motivation, without (unlike in active participation) inducing anxiety. On the other hand, the disputative tone may vicariously induce anxiety or cause the reader to invest less cognitively, by which it may have an adverse effect on learning. We then sought to explore how different argumentation styles would affect learning from reading online FB discussions.

## Method

A FB discussion was created revolving around a hot topic in Israeli society: Whether legal work permits should be issued for African refugees/asylum seekers/work immigrants (AAs). Twelve existing online articles on related topics were selected to reflect a variety of opinions and aspects. Each discussion contribution contained a claim, argument and/or a question by one of 4 (fake) discussants, as well as a link to one of the abovementioned online resources as support. Based on earlier work (Asterhan, 2013; Asterhan & Babichenko, 2013), two versions were created, with identical content, but differing in argumentative discourse style (see Table 1 for examples).

Sixty undergraduates from a large Israeli university (mean age = 25.10, 13 male) participated in a 1×3 randomized experiment. The experimental session (60-80 min) included the following activities: (1) a demographic and an attitudes survey; (2) writing an argumentative essay on AA employment and an attitudes survey; (3) the experimental session (see below); (4) a declarative knowledge test containing closed and open questions on facts from the online resources; and (5) writing another argumentative essay. During phase 3, subjects in the two discussion conditions were told that they were about to read an educational discussion between students as part of their requirements for a Social Studies class, who were instructed to support their arguments using links to online resources. In the control condition, the subjects only received the article titles and links to the articles, along with the source and date of each. The data collected in this study then consisted of 3 online questionnaires, 2 essays (pre and post) and screen-recordings of the subjects' screen actions. In this paper, we report on the effect of the conditions on students' performance on the declarative knowledge test.

**Table1:** Excerpt of the FB group discussion content according to two different argumentative discourse styles

	<i>Disputative style</i>	<i>Deliberative style</i>
Ronit:	<b>It's obvious</b> that we <b>have</b> to let the refugees work, so that they can make an honest living and contribute to our society. Otherwise they'll be lying in the streets and will depend on charity or crime in order to have something to eat, and <b>we can see</b> that crime amongst them is <b>really</b> on the rise. [LINK]	<b>I think</b> we should let the refugees work, so that they can make an honest living and contribute to our society. Otherwise <b>I fear</b> they'll be lying in the streets and will depend on charity or crime in order to have something to eat. <b>Unfortunately for us it seems that</b> crime amongst them is <b>indeed</b> on the rise. [LINK]
Limor:	<b>You're talking nonsense! Do you mean to tell me that they commit crimes because they don't have anything to eat? And what about all the rapes we hear about?</b> [LINK]	<b>But perhaps we should think about another solution</b> to crime, <b>because there are all these rape cases we've heard about recently that I'm not sure are related to</b> not having anything to eat. [LINK]

## Results and Discussion

No differences were found between the three conditions in students' attitudes towards AIs prior to the intervention,  $F < 1$ . A  $1 \times 3$  ANOVA on students' performance scores on the content knowledge test showed a significant effect of condition,  $F(2,57) = 6.55, p = .003, \eta^2 = .187$ . Post-hoc tests (with Tukey-Kramer adjustments) revealed that students in the disputative discourse style condition showed less content knowledge ( $M = 56.67, SD = 12.64$ ) than both the deliberative discourse style condition ( $M = 67.62, SD = 8.96, p = .016$ ) and the control condition ( $M = 69.52, SD = 14.19, p = .004$ ). Performance scores of students in the control and the deliberative discourse style conditions were similar ( $p = .873$ ). Previous studies have shown that participation in disputative (as opposed to deliberative) argumentative discourse is associated with lower individual knowledge gains from verbal interaction (Asterhan & Babichenko, 2013). The findings reported here then further extend these findings to a setting in which students read (as opposed to participate in) disputative discussions. The fact that no differences were found between the deliberative and the control condition seems to indicate that the effect of rhetoric style in argumentation may not be a positive outcome of deliberative argumentation, but a negative outcome of disputative argumentation. It is possible that the disputative discourse style caused learners to adopt more superficial strategies while reading the discussions and the accompanying online resources (Bliuc et al., 2010; Wise et al., 2013). Analyses of the screen-recording data and the argumentative essays are expected to provide further insights into the processes that led to the differences in knowledge gains results, and will be presented at the symposium. In any case, the findings reported here show that vicarious participation in argumentative SNS discussions can have similar effects to reading information sources only, but that particular attention should be dedicated to the rhetoric style of such discussions.

## Differential Effects of Scripts for Learning in Facebook: Individual Preparation and Argumentation Scripts

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As SNS are a natural platform for dialogic exchange, they can be used for learning through argumentative knowledge construction (AKC; Weinberger, Stegmann, Fischer & Mandl, 2007). Scripts are commonly used to enhance knowledge co-construction (Weinberger, Stegman & Fischer, 2007; Fischer, Kollar, Stegmann & Wecker, 2013; Andriessen, 2006) by structuring argumentation in order to help discussants clarify their own ideas and consider new ideas by others. Should scripts also be used to promote argumentative learning in FB, which is associated with informal self-directed learning? To answer this question, the benefits and risks of using scripts in SNS and their potential interactions with SNS affordances have to be clarified. Here we explore two kinds of scripts, individual preparation (where students are granted extra time to prepare their arguments before collaboration) and argumentation scripts, and their effects on knowledge co-construction and outcomes in three studies set up in FB. We look into two implementations of argumentation scripts: In Study 1, an argumentation ontology was implemented in LASAD (Loll & Pinkwart, 2013) to script argumentation prior to discussing in FB (Tsovaltzi, Weinberger, Scheuer, Dragon, & McLaren, 2012). For Study 2 and 3, we built a FB App with typical FB-functions - "like" and "comment" - which implemented the ontology directly inside FB (see Figure 1).



Figure 1. The FB-app with argumentation script

## Study 1

This pilot study ( $N=40$ ) analyzed the influence of individual preparation with an argumentation script (LASAD) on subsequent knowledge co-construction discussions in dyads inside FB with a  $1 \times 2$  design (Tsovaltzi et al, 2012). The results showed that both conditions changed their opinions and general attitude towards behaviorism

as a teaching strategy,  $t(39)=8.84$ ,  $p<.001$ ,  $d=1.40$ , but there were no differences between groups,  $F(1,38)=.09$ ,  $p=.77$ . Moreover, both conditions shared more knowledge post intervention,  $F(1,18)=19.61$ ,  $p<.001$ , *partial  $\eta^2=.52$* , which is a strong indicator of transactivity (Weinberger et al, 2007). Although both conditions learned significantly from pretest to posttest,  $F(1,38)=87.55$ ,  $p<.001$ ,  $\eta_p^2=.70$ , opinion change, as an additional measure of transactivity (Wood, Kallgren, & Priesler, 1985), correlates with knowledge gains only in the condition without argument support. This might be an indication that individual preparation with an argumentation script before collaborative discussion may hinder knowledge co-construction; learners gain knowledge, but not jointly. Is the individual preparation per se or the argumentation script responsible for the missing correlation between knowledge gains and opinion change? Does individual preparation lead to lack of knowledge co-construction?

## **Study 2**

In a  $2\times 2$  individual design we examined argumentation scripts and group awareness support in a university course ( $N=81$ ) (Tsovaltzi, Puhl, & Weinberger, 2013). A FB App implemented the argumentation script. Group awareness was supported in the awareness conditions by informing participants that selected arguments would be published in the course forum where they could be assessed, amended or refuted. Such group awareness is a standard FB affordance; when asynchronously creating posts users are aware that their arguments will be assessed, amended or refuted, common practices in FB, but also explicitly “liked” or implicitly “not liked” by an audience with access to personal information about them. Results indicate that all groups learned between pretest and posttest,  $F(1,77)=221.73$ ;  $p=.000$ ,  $\eta_p^2=.74$ . Helmert contrasts showed that the control was better than the condition with group awareness support only,  $t(77)=2.52$ ,  $p=.014$ ,  $d=.86$ , indicating negative effects of group awareness support. There were no similar effects for argumentation script. It is possible that group awareness support in individual preparation declines the quality of argument preparation and hinders learning, but argumentation scripts may counteract this effect. How do argumentation scripts influence learning when users are scripted to individually prepare before discussing in FB, where group awareness described above is granted?

## **Study 3**

We tested this question in a  $2\times 2$  study with university students ( $N=128$ ), with factors argumentation script (operationalized as in study 2) and individual preparation (Judele, Tsovaltzi, Puhl & Weinberger, 2014). All participants were given instructions to exchange arguments during collaboration and reach a common conclusion, as in standard argumentative collaborative scenarios. Time on task was held constant but discussion differed depending on the condition. Therefore, we relativized our results for time. There was a large main effect on learning gains,  $F(1,124)=124.27$ ;  $p=.000$ ,  $\eta_p^2=.50$ , but a negative main effect of individual preparation on learning outcomes,  $F(1,124)=5.121$ ;  $p=.025$ ;  $\eta_p^2=.04$ . There was no main effect of argumentation script,  $F(1,124)=0.04$ ;  $p=.847$ ;  $\eta_p^2=.00$ . To decipher the effects of argumentation script on learning gains, we compared argumentation script only to individual preparation with argumentation script, which was significant for argumentation script only,  $t(124)=2.9$ ,  $p=.005$ ,  $d=0.69$ . Moreover, there was a main negative effect of individual preparation for knowledge equivalence (Weinberger, Stegmann & Fischer, 2007),  $F(1,60)=4.32$ ;  $p=.042$ ;  $\eta_p^2=.07$ . Taken together, these results support the interpretation that individually preparing arguments before collaboration leads to worse learning outcomes independent of argumentation script and that there is less knowledge co-construction for learners with individual preparation.

## **Interpretation**

The negative effects of individual preparation (studies 1 and 3) contradict previous results in computer supported collaborative learning (CSCL). Together with the negative effect of group awareness support (Study 2) they may signify that social aspects (self-presentation and caution) are magnified in the context of FB (even in a closed FB App) with detrimental effects for learning. However, the argumentation script during individual preparation did not counteract these negative effects (Study 3), although it significantly increased learning when provided during collaboration. This difference to standard CSCL findings could also be explained if we consider the socially loaded context of FB. It is plausible that users used the script to prepare well during individual preparation in order not to lose face in the FB discussion. This may have led to undue knowledge solidification rather than preparation for knowledge co-construction. Although further research is on call, these collective results implicate that to leverage FB as a learning platform we need to offer guidance (e.g. argumentation script) but at the same time respect FB affordances like asynchronous dialogic communication.

## **Argumentation and Civic Engagement in a Facebook App**

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Increasingly, learning scientists are exploring the nature of adolescent collaborative learning in a variety of settings such as schools, museums and out-of-school media practices in virtual environments. Socio-cultural learning theory and theories of computer-supported collaborative learning have suggested that such contexts

might be particularly supportive of learning because a considerable amount of learning occurs through informal interactions with others (Brown, Collins & Duguid, 1989). Our work was also framed by the larger discussions surrounding the development of *scientific literacy* (Polman et al., 2010) and *communication competence* (McLeod et al., 2010) as a dimension of civic competence and actual civic engagement. These discussions emphasize learners' integration and validation of information from multiple sources; formulation of arguments; multiple perspective-taking; expression of opinion; making connections between issues that yield more complex issue understanding; actively engaging others in collective action, and multiple routes to civic participation. Thus, the focus of the current study was to examine the links between socio-scientific argumentation, civic communication competence, and civic engagement in a Facebook application.

## Methods

Participants in this study were not part of any formal educational program or course but interested in environmental science, as indicated on an initial registration survey. Participants were accessed through substantial marketing efforts and partnership with campus- and school-based environmental groups. Hot Dish (HD) was an open-source FB application designed to facilitate information-sharing, commentary, and problem-solving 'challenges' about environmental science topics. In Hot Dish, users could post original articles or circulate online articles; as well as read, share, vote on, and comment on posted articles. The overall HD community comprised 346 consented participants (ages 16-24) who contributed 3,000+ postings of comments, blog entries, and challenge documentation. This paper focuses on a subsample drawn from the larger HD community based on their participation in commenting on posted stories ( $n = 31$ ). These participants posted over 950 unique comment strings in response to posted articles across 256 of articles.

The focus of this study was on the comments that users posted in response to articles. We coded for argumentation along six process-oriented *argumentation* dimensions: (1) Counterarguments, (2) Arguments, (3) Integrated Replies, (4) Epistemic skills, (5) Conflict-oriented Consensus Building (COB), and (6) Quick Consensus Building (QCB) (Greenhow, Menzer & Gibbins, 2012; Sadler et al, 2006; Weinberger & Fischer, 2006). Each comment string (unit of analysis) was coded for argumentation, and means were calculated for each skillset at the comment string level. We also coded comment strings for the presence of five indicators of *civic communication competence* (McLeod, et al., 2010): (1) information from multiple sources (INFO), (2) expression of opinion (EMO), (3) learning from peers (LRN), (4) making connections between issues (that presumably yield more complex issue understanding) (CP), and soliciting others' civic participation (SC).

Lastly, users completed problem-solving 'Challenges' (i.e., *civic engagement opportunities*) designed to address environmental issues in users' communities through online or offline activities, such as recycling or signing up for an online newsletter about environmental issues (Heimlich & Ardoin, 2008). There were 56 challenges that each user was invited to complete. Civic Engagement was coded across challenges for four different levels: Platform (online, offline, hybrid); Activity Type (volunteer, activism, individual); Participation Type (expressive statements, civic community participation, campaign political participation, political consumerism), and Citizenship Style (dutiful, actualizing) (Bennett, Freelon & Wells, 2010). Codes outlined above will be described with examples from the data in the final paper and presentation.

## Results

Means, standard deviations, and correlations of argumentation and communication competence are presented in Table 2. In terms of argumentation skills, users on average, produced Epistemic skills, followed by Arguments and Integrated Replies; and the relations between argumentation skills varied (e.g., Greenhow et al., 2012). In terms of civic communication competence, most users, on average, produced expressive statements and solicitations for civic engagement.

Table 2: Means, Standard Deviations, and Bivariate Correlations

	1	2	3	4	5	6	7	8	9	10	11
1. Counter-argument	--	.062	-.103***	.214***	.404***	-.117***	.146***	-.136***	-.021	-.121***	.092**
2. Argument	--		-.131***	.304***	.044	-.272***	.084**	-.055	-.069*	-.367***	.305***
3. Integrated Reply		--	.030	-.200***	-.027	.008	-.104***	.024	-.092**	.101**	
4. Epistemic			--	.164***	-.375***	.182***	-.049	-.019	-.469***	.212***	
5. COB				--	.018	.085**	-.083**	-.046	-.086**	-.060	
6. QCB					--	-.042	.051	.040	.348***	-.200***	
7. INFO						--	-.075*	.015	-.096**	-.009	
8. EMO							--	-.036	.094**	.000	
9. LRN								--	-.069*	-.024	
10. SC									--	-.343***	
11. CP										--	

<i>Mean</i>	0.09	0.26	0.22	0.38	-0.05	0.11	0.06	0.39	0.06	0.24	0.36
<i>SD</i>	0.24	0.29	0.42	0.25	0.71	0.31	0.23	0.49	0.24	0.43	0.48

Note:  $N = 971$  comment strings. \*  $p > .05$ . \*\*  $p > .01$ . \*\*\*  $p > .001$ .

Of most interest were the links between argumentation and civic communication competence. Correlational analyses revealed that using multiple sources of information, an indicator of civic communication competence, was positively related to most argumentation skills. Posted comments demonstrated evidence of argument construction (Greenhow, Menzer & Gibbins, 2012) and multiple sources of information. Another indicator of civic communication competence: solicitations of civic participation found in comment strings, was also positively related to most argumentation skills. Expressing emotions was negatively related to most argument skills, suggesting that ‘heated debate’ was less representative of argumentation skills in this community than in other youth-initiated social network sites (Greenhow & Robelia, 2009).

Across all users, Hot Dish users completed 1173 problem-solving challenges during the 8-week period across 56 unique challenges. Codes regarding the number of challenges comprising each of the four different levels of civic engagement (platform, activity type, participation, and citizenship style) and the number of challenges completed for each type are presented in Table 3.

**Table 3: Civic Participation Challenges**

Civic Participation Challenges	Number of Unique Challenges	Number of Completed Challenges
<i>Platform</i>		
1. Online	24	466
2. Offline	28	688
3. Hybrid	1	6
<i>Activity Type</i>		
4. Volunteer Activity	17	387
5. Activism	25	586
6. Individual	11	187
<i>Participation</i>		
7. Expressive Participation	28	549
8. Civic Community Participation	8	222
9. Campaign Political Participation	6	163
10. Political Consumerism	10	140
<i>Citizenship</i>		
11. Dutiful Citizenship	11	346
12. Actualizing Citizenship	41	700

## Discussion and Implications

Based on prior research, we speculated that argumentation would be related to civic communication competence in various ways. Results reveal the complexity in which argumentation skills are associated with civic communication competence skills. We also speculated that young people’s enacted civic engagement would align less with traditional theories of dutiful citizenship (voting, party or organization activity) and more with new theories of actualizing citizenship (individual activism, issue-oriented activity online) that seem particularly synergistic with the affordances of social media. This proved to be true: Twice the number of civic opportunities coded as actualizing were completed ( $n=700$ ), compared to those coded as dutiful ( $n=346$ ). The final presentation will further discuss our results along these dimensions: socio-scientific argumentation, civic communication competence, and civic engagement in a Facebook application; the links between them, and implications for future work.

## Group Awareness and Reflection Scripts: Learning Effects of Facebook-Based Seminar Interactions

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Learning in FB may be particularly suited to facilitate online learners’ group awareness, i.e. help them consider the audience and the group processes, like sympathizing with or criticizing. Group awareness seems to be positively related to performance and to process satisfaction of computer-supported learning groups (Phielix et al., 2010). Awareness tools are used to share information about learners, such as individual knowledge (cognitive awareness), group processes or attitudes (group awareness). Awareness can foster positive the collaboration process, especially though controversial computer-supported discussions (Buder & Bodemer, 2008). Scripts have been successful in helping students structure, reflect and discuss their opinions (Weinberger et al., 2007) and promote knowledge co-construction, argumentative and declarative knowledge (Weinberger & Fischer 2006). We tested the effects of group awareness and reflection scripts in FB on learning gains and attitude change in three seminars on communication theory over eight weeks. Learning gains is the standard measure for

cognitive change. Learning as development of personality in terms of attitude change is less commonly connected to formal education, but its importance is recognized in vocational training which includes training on professional attitude and communication, e.g. of medical doctors, lawyers, teachers. Theory on attitude change supports that change is the result of dissonance that can be caused by cognitive (attitude) conflict or conflict between cognition and behavior. Such conflicts can be raised through cognitive perceptions, or cognitive and affective (commonly social) perceptions (Erber, Hodges, & Wilson, 1993; Eagly & Chaiken, 1995).

## Methods

A  $1 \times 3$  quasi-experimental field-study with German teacher trainees ( $N=62$ ) investigated the effects of group awareness with and without a reflection script on learning outcomes and attitude change. During a seminar on communication and interaction, students weekly answered a case-based communication questionnaire with cases from every-day school interaction from the perspective of a teacher. Every scenario included four Likert-scaled answers, two capturing multiple perspectives and flexible attitudes (emphasizing the perspectives of different parties in conflicts), and two answers capturing goal-oriented and structured attitudes (opting for clear directions), rated on a scale from 0 to 12. Every week, before discussing seminar contents in their FB group, the results of the questionnaire were played back to the participants in an awareness tool, a two dimensional graphic within a FB-app, where students could see their own and the group's position depicting communication attitudes. Following Dillenbourg and Hong (2008) the tool was aimed at inducing dissonance between the theories students studied in the seminar and their personal attitude as shown in the tool. To enhance this dissonance, the second experimental group also received a weekly macro script to structure their reflection (e.g. how does my position change?) and the behavioral outcome (e.g. discuss with the person most different from you) of the awareness tool. We hypothesized that more change should occur in the experimental conditions and the direction of change would be more varied in relation to the seminar contents than in the control. In terms of the learning outcome, we hypothesized a main effect of group awareness on declarative knowledge (facts and definitions) and argumentative knowledge (theory-based interpretations and argumentation).

## Results

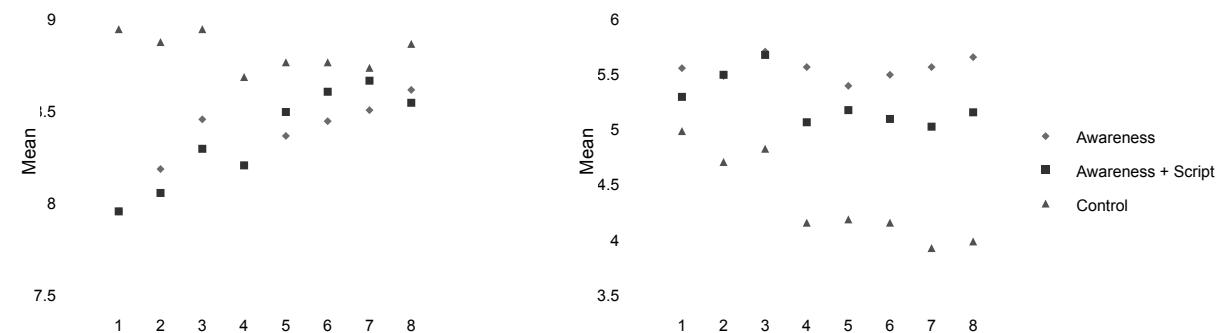


Figure 2. Multiple-perspective / flexible attitude

Figure 3. Goal-oriented / structured attitude

There were no significant differences between groups prior to the intervention. Log data confirmed that both awareness groups spent time looking at the graph as an indication of reflection, and that the script condition reflected on their graph position. There is a significant effect for the experimental groups on declarative knowledge,  $F(2;59)=6.86$ ;  $p=.002$ ;  $\eta_p^2=.19$ , i.e. both awareness conditions learned more about facts and definitions, and. There are no significant effects for argumentative knowledge. An explorative factor analysis identified two factors of communication attitudes. The first factor is a multiple-perspective and flexible way to reflect on and behave in the scenario, the second factor is a goal-oriented and structured way. A repeated measures ANOVA showed a significant effect of the experimental conditions for the factor multiple-perspective / flexible attitude (see Figure 2),  $F(2;59)=1.72$ ;  $p=.049$ ;  $\eta_p^2=.06$  and for the factor goal-oriented and structured attitude (see Figure 3),  $F(2;59)=1.98$ ;  $p=.018$ ;  $\eta_p^2=.06$ . The descriptive statistics show that the experimental conditions score higher in their communication attitude for the first factor. On the contrary, the control, which starts on a significantly higher level in the first week,  $F(2;59)=3.26$ ;  $p=.046$ ;  $\eta_p^2=.10$ , remains relatively stable over the duration of seminar. The awareness groups started on an average level, changing their attitudes towards more multiple-perspective over the duration of seminar. However, the control scored gradually lower on the second factor until the end of the seminar, whereas the awareness conditions were rather stable in their attitudes. Contrast showed that both awareness conditions changed their attitude from first and to last session significantly on multiple-perspective,  $t(59)=2.70$ ;  $p=.010$ , which also correlates with learning outcomes on declarative knowledge,  $r(61)=.26$ ,  $p=.046$ , and the control condition on goal-oriented behavior,  $t(59)=2.64$ ;  $p=.011$ .

## **Discussion**

As hypothesized, it seems like the increased awareness of one's own position in the graphic increased the dissonance between cognitive and affective state at the individual level, which led to reflection on the seminar topic for the individual, who tried to understand their position (communication type) based on communication theories. At the same time, the awareness of the one's relative position with regard to the seminar group increased the dissonance between cognitive and affective state at the group level, causing students to turn to the seminar material in order to mutually explain and understand differences and similarities. The awareness tool implemented in FB induced this behavior without the script that we hypothesized would be necessary based on previous learning science results. Although an attitude change of the awareness conditions only took place for the multiple-perspectives factor, this process resulted in increased declarative knowledge. The correlation between the change on multiple-perspectives and declarative knowledge supports this interpretation. For the control, the seminar topics constituted a rich source of information that could saturate the curiosity inflicted by the socio-cognitive dissonance. This richness, in lack of awareness, might have cancelled out the expected effects of using the fellow students to exchange arguments in a process of knowledge co-construction that was expected to increase declarative knowledge. Another interpretation could be that the high scores in multiple-perspectives and the simultaneous support for this behavior by the seminar content prevented any change for the control; however, this is not supported by the significant lower knowledge outcomes for this condition. For the goal-orientation factor, the control changed their attitude to disfavor this communication strategy, presumably through a superficial impression shared by the seminar at first glance that this strategy is not favored. The lower learning outcomes would explain this impression. In addition, the awareness conditions demonstrated the attitude that the seminar aimed to cultivate; namely, an understanding that some situations require more goal-oriented and structured approaches, although multiple perspectives are in general required.

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# Enhancing Self-Regulated Learning through Metacognitively-Aware Intelligent Tutoring Systems

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**Abstract:** This symposium identifies current trends and future directions in research on metacognition and Self-Regulated Learning (SRL) in educational technologies, and specifically, Intelligent Tutoring Systems (ITS). Each paper will elaborate on detection and assessment of metacognition/SRL, forms of support and scaffolding, and self- and co-regulation processes and authoring of environments that support ITS. The symposium will conclude with discussions that describe the manner in which metacognitive development can be promoted through strategies that support individual differences in multiple contexts. The alternative perspectives presented in this session will help advance our understanding of support for metacognition and SRL in ITS, as well as identify gaps that will influence future research pursuits.

## Overall Focus of the Symposium

Intelligent Tutoring Systems (ITS) are designed to manage and regulate learning experiences within a specified domain. While shown to be effective in helping individuals gain new knowledge and learn problem solving procedures, a typical ITS confines its pedagogical approach to the domain material alone, with little emphasis on promoting metacognitive learning strategies that are general across domains. Recent research strives to enhance such systems through the incorporation of tools and methods that promote Self-Regulated Learning (SRL) by incorporating strategies linked to metacognitive awareness and regulation. Metacognition is often described as being made up of two constituent parts: (1) *Metacognitive knowledge*, which is declarative and deals with the interplay between knowledge of one's abilities to perform tasks, the nature of the task, and the strategies one can employ to successfully perform the task; and (2) *Metacognitive regulation*, which includes activities related to goal selection, planning, monitoring, control, and reflection (Flavell et al., 1985; Schraw et al., 2006; Veenman, 2012). Because metacognition involves the explicit management of one's own cognitive resources, there exist strong interrelationships between learners' metacognitive abilities and their understanding of, familiarity with, and effectiveness in executing the cognitive tasks required for success (Bransford, et al., 2000; Winne, 1996). Thus, tutors in open-ended environments must be able to measure and interpret student behaviors at both the cognitive and metacognitive level in order to provide support for both types of mental processes (Biswas, et al., 2010; Land, 2000; Kramarski, 2004; Roll, Aleven, McLaren, & Koedinger, 2007). The purpose of this symposium is to present current research and perspectives that address this problem space from relevant experts in the field.

This session includes four papers that adopt the common theme of using technology-based instructional systems to help students become more independent learners. Presentations will cover research derived from models and constructs linked to SRL, modeling and monitoring techniques to gauge students' cognitive and metacognitive abilities, defined strategies and tactics for guiding and improving metacognitive processes, and implications for developing authoring tools to facilitate monitoring, modeling, and scaffolding metacognitive processes in an ITS. Collectively, the presentations will be oriented toward discussing pragmatic issues associated with supporting metacognition and SRL in ITSs, and how the application of metacognitive strategies can enhance learning outcomes as they relate to improved learning performance and transfer. As metacognition deals with one's awareness of the knowledge and regulation of cognition, it is important to understand the distinctions between these two parts and how they compliment learning within SRL environments that are open-ended in nature. In turn, ITS developers need to understand how individuals apply metacognitive strategies to

fully embed modeling techniques and pedagogical strategies that fit within the theoretical constructs of how students regulate resources and emotions when learning. This includes looking at various modeling approaches that take into account theoretical foundations associated with a domain, along with methods to monitor actions in an environment to identify patterns of successful behavior that may be linked to metacognitive strategies. In addition, the use of instructional strategies to improve students' metacognition must be explored, looking both at triggers (i.e., static vs. adaptive) and distinguishing characteristics of strategies as they relate to the varying processes linked to learning (i.e., cognition, behavior, motivation, and affect). Furthermore the application of ITS technologies outside of academic settings (i.e., K-12) is becoming more prevalent, with a push for systems to support simulations in real-world contexts. Student profiles and learner models must now accommodate the life-long adult learner. Implications for tailoring systems to support individuals in varying phases of their life and career must be identified, as these characteristics will dictate how systems will adapt to aid in the development of independent learning skills. In addition to establishing a foundation for how to assess and instruct metacognitive behaviors, we describe tools to author these mechanisms into an Intelligent Tutor.

## **A Combined Theory- and Data-Driven Approach for Interpreting Learners' Metacognitive Behaviors in Open-Ended Learning Environments**

Gautam Biswas, James R. Segedy, John S. Kinnebrew, ISIS/ Department of EECS, Vanderbilt University

Adapting to learners' needs and providing useful individualized feedback to help them succeed has been a hallmark of most intelligent tutors (Anderson, et al., 1995; Gertner & Van Lehn, 2000). More recently, to promote deep learning, critical thinking, and problem-solving skills in STEM disciplines, researchers have begun developing tutoring systems that present learners with complex problems and a set of tools for learning and problem-solving (Hannafin, 1994; Land, 2000). To be successful in such open-ended learning environments (OELEs), learners must be metacognitively aware, apply metacognitive strategies that promote effective learning, and manage, coordinate, and reflect on their use of a number of cognitive processes to succeed in their learning and problem solving tasks (Bransford et al., 2000; Zimmerman, 2001). A typical learning task may combine a number of activities, such as searching for information, interpreting information in the context of the learning and problem solving tasks, and applying it to the construction and testing of potential problem solutions. This can present significant challenges to novice learners; they may have neither the proficiency for using the system's tools nor the experience and understanding necessary for explicitly regulating their learning and problem solving (Chi et al., 1988; VanLehn, 1996). Furthermore, their abilities to reflect on past activities and relate them to task outcomes may not be well developed (Schunk & Zimmerman, 1997). Not surprisingly, research has shown that novices often struggle to succeed in such complex environments.

### **Measuring Metacognition in Open Ended Learning Environments (OELEs)**

Adaptive tutoring systems regularly capture and analyze student activities in order to make decisions about how and when to scaffold learners. However, the complexity of OELEs poses considerable challenges to accurately interpreting and understanding student behaviors. Traditionally, learning behavior is assessed with top-down metrics based on theory and hypotheses about student learning activities in the context of their learning tasks (Hmelo-Silver, 2004; Segedy, Loretz, & Biswas, 2013). In recent years, however, bottom-up data mining techniques that analyze students' logged activity data have been utilized to discover important aspects of how students learn (Kinnebrew, Loretz, & Biswas, 2013). We present a framework for analyzing learning activity data in OELEs that combines top-down metrics and bottom-up pattern discovery. This integrated framework can be employed to build detailed models of students' learning behaviors and strategies, and subsequently to identify opportunities for providing adaptive scaffolds to students as they use the system.

For top-down, theory-driven analysis of learning behaviors, our framework focuses on (i) the learner's acquisition and application of knowledge and information encountered while they perform their task-related activities in the OELE and (ii) the impact of these activities with respect to the learning task (e.g., whether an action directly resulted in progress toward completion of the task). For bottom-up, data-driven discovery of learning behaviors, our framework employs data mining techniques for identifying frequent patterns of action in logs of their activity in the environment. Our approach enhances the analysis and assessment of student learning behavior by combining these complementary top-down and bottom-up techniques. This allows us to identify specific learning behaviors for a group of students, behavior differences between groups that are relevant to understanding their approach to learning in the environment, and the connections between specific patterns of activity and the relevant skills or strategies for learning and problem solving. More specifically, the theory-driven metrics are used for evaluating and differentiating instances of the discovered patterns in order to better understand whether or not the discovered patterns were used as part of coherent strategies and, if so, which ones. The theoretical measures also provide valuable information about individual differences among students that may employ the same pattern of actions but in different manners or for different purposes. Therefore, this

analysis framework provides concrete results in the form of action patterns with associated measures that are linked to relevant learning strategies and behaviors.

### **Case Study: Application to the Betty's Brain OELE**

Betty's Brain is an open-ended learning environment (Biswas, et al., 2005) that provides students with a learning context and a set of tools for pursuing authentic and complex model building tasks. Students working in the Betty's Brain system are expected to apply a number of cognitive skills that relate to the four primary activities that the students can perform in the environment: (1) read and understand the science content, (2) translate the relevant content into specific causal relations to build the causal map to teach Betty, a computer agent, (3) check the correctness of the causal map by asking Betty questions and getting her to take quizzes, and (4) use the quiz and question results to identify the correct, incorrect and incomplete parts of the map. Together (1) and (2) are referred to as *Knowledge Construction* skills, and (3) and (4) are referred to as *Solution Evaluation* skills. Building up from the cognitive skills, we hypothesize four categories of metacognitive strategies that students need to develop and deploy in the Betty's Brain environment: (1) Goal Setting & Planning, (2) Knowledge Construction, (3) Solution Evaluation, and (4) Help Seeking (Kinnebrew, Segedy, & Biswas, 2014).

An important aspect of our hierarchical task model is its non-linearity; students are expected to continually navigate among the cognitive and metacognitive processes as they go about their task of teaching Betty a correct and complete map of the domain. Thus, this model also serves as a framework for interpreting students' learning activities and activity sequences that we characterize as learning behaviors. This matches other approaches (e.g. (Hadwin et al., 2007)) that describe students' evolving metacognition in terms of a sequence of events using trace methodologies. The structure of the model also implies that it is unlikely students can be effective in metacognitive strategies unless they are proficient in the related cognitive strategies.

Our analytic framework for analyzing OELE learning activity data comprises extracting sequences of canonical actions from log files of student activities, sequential pattern mining to identify common action patterns, mapping identified patterns back into action sequences to analyze them with the theory-driven measures in the context of the students' other activities, and linking the identified behaviors (described by both a sequential pattern of actions and the relevant measure values that distinguish it from other instances of the same action pattern) to skills and strategies in the cognitive/metacognitive task model. To assess a student's metacognitive regulation, our approach evaluates student behaviors using a measure of coherence called *action support*. Support for a particular student action represents the extent to which it is informed by information gained from previous actions. For example, information seeking actions (e.g., reading about a causal relationship) can provide support for future solution construction actions (e.g., adding the corresponding causal link to the map). Students with higher proportions of supported actions are considered to have a higher mastery of strategies for coordinating their use of tools within the environment.

We present results from analyzing data from recent studies with Betty's Brain that we have run in middle school science classrooms. The results of this analysis provide a foundation for developing performance- and behavior-based learner models in conjunction with adaptive scaffolding mechanisms to promote effective, personalized learning experiences.

## **Assessment and Instruction of Self- and Co-Regulation of Medical Diagnostic Processes in Technology-Rich Learning Environments**

Susanne Lajoie and Eric Poitras, McGill University

Broadly speaking, learning is often described in terms of the relationship between what goes on in the mind and how the environment influences what is learned. By environment we refer to: the learning materials presented in or outside of class; the real or augmented context; the presence and influence of others (human or computer-supported) be they peers, tutors or teachers, and; the structure of the environment (ill-structured or structured). We are seeing an evolution in the constructs of SRL that better articulate the components of the environment that need to be considered in defining and supporting SRL. In this paper, we describe BioWorld (Lajoie et al., 2013), a computer based learning environment (CBLE) in terms of how it supports learners' SRL of diagnostic reasoning processes while solving virtual patient cases.

### **Fostering Regulatory Processes in Diagnostic Reasoning with BioWorld**

The social cognitive perspective of SRL states that self-regulation involves cognitive, affective, motivational, and behavioral activities that are planned and adapted in order to attain a goal, such as solving a problem (Zimmerman, 2000). Problem-solving processes occur in three phases: forethought, performance, and self-reflection. Self-reflection processes occur after performance efforts, and in turn, influence forethought in relation to subsequent steps taken to solve the problem. SRL processes are recursive in that feedback from prior performance informs subsequent adjustments efforts (Zimmerman & Campillo, 2003). We apply SRL theories to phases of problem-solving processes relevant to domain-specific knowledge involved in diagnostic reasoning.

BioWorld is designed to foster SRL by supporting cognitive and metacognitive activities that are critical in diagnosing virtual patient cases. Forethought processes involve learners' efforts to orient themselves to a patient problem, and plan the necessary next steps. Self-regulated learners activate their prior knowledge of disorders in response to relevant information pertaining to the case in an effort to list hypothetical diagnoses. A typical learner might then formulate a plan to order a lab test that will confirm the most likely diagnosis, look for particular information from the library, or seek external help by asking for a consult. During the performance phase, learners execute the steps, and then monitor the outcomes. After receiving the outcomes of a lab test for instance, learners determine whether the results are pertinent or non-pertinent to the diagnosis. In doing so, learners might determine that their overall understanding of the case improved, or if their test results are unexpected, or contradictory, confusion may occur which may lead to a re-evaluation of the plausibility of the tentative diagnoses. Self-reflection processes consist of learners' evaluation of and elaboration on their overall progress in problem solving. Self-regulated learners check the relevant evidence and symptoms, while at the same time verifying each hypothetical diagnosis. A typical learner connects evidence and relevant information by drawing conclusions and updating their confidence in each diagnosis.

### **Assessing Novices along the Trajectory towards Expertise**

A learner model is a computational representation of learner characteristics that includes relevant states pertaining to knowledge and skill acquisition as inferred through their interaction with the learning environment (Shute & Zapata-Rivera, 2012). The representation of relevant learner characteristics is continually updated throughout the learning session as they practice their skills. Learner interactions are recorded and analyzed by the CBLE with the aim of guiding instruction. Table 1 shows an overview of learner modelling techniques used for the purposes of assessing SRL in BioWorld. The current version of BioWorld implements a novice-expert overlay model to deliver feedback. This method relies on the comparison of novice actions to the expert solution trace. These actions are recorded through the evidence palette, which is designed to assist novices in orientating themselves to the problem space (i.e., patient symptoms highlighted in case description, relevant library information accessed, lab tests ordered etc.). The feedback palette shows similarities and differences between the novice and expert solution paths on these key processes.

Table 1: An overview of learner modelling techniques used to assess self-regulation in BioWorld.

SRL phase	Tool description	Learner modeling method	Data channels	Measures
<i>Implemented in BioWorld version 2.1</i>				
Forethought	Evidence palette	Overlay method	Action attributes	Log file trace
<i>Under development for BioWorld version 3.0</i>				
Performance	Library	Machine learning method	Action attributes	Log file trace
	Consult tool	Machine learning method	Linguistic attributes	Think aloud
Self-reflection	Case summary	Machine learning method	Linguistic attributes	Log file trace
	Feedback palette	Quantitative modelling	Affective/Motivational attributes	Self-report

We are using a data-driven approach that uses educational data mining techniques to redesign components of BioWorld's learner model. First, we have created a decision tree classifier that allows BioWorld to trace Novice library searches and infer whether the library topics explored leads novices to engage or disengage from the expert solution path. Data from the library classification model stands to improve instruction through the recommendation of specific topics in the library. Second, we examined the novice think-aloud protocols and clustered them based on sequences of cognitive and metacognitive activities, outlined by the SRL model, that occur prior to asking for a consult in BioWorld. The cluster model allows researchers to tailor the content of hints delivered by the consult tool in response to different profiles of help-seekers.

Although these models targeted different aspects of task performance, the following tools are designed to support novices in reflecting about their own approach to solving the problem. We evaluated the written patient case summaries using a neural network classifier to assess disease type and correctness of diagnosis on the basis of linguistic features. We plan to broaden the scope of the text classification model to provide novices with feedback on the quality of case summary sections and instruction on text writing strategies. Finally, we expanded the scope of the SRL model by modelling the impacts of achievement emotions and goals towards attention given to feedback in BioWorld. The logic model allows the system to assess learner characteristics

through self-report, and direct novices' attention to aspects of the feedback that are most often overlooked by learners with a similar profile of characteristics.

### **Developing a Community of Co-Regulated Problem-Solvers**

BioWorld serves as a platform to develop a community of practice, using cognitive apprenticeship principles to deliver instruction that brings in expertise from outside the classroom to the learning environment. We involve expert medical instructors in the case creation and expert knowledge building by having them use CaseBuilder, an authoring tool designed to allow domain experts and researchers to modify cases and explore instructional activities. Expert problem-solving traces are collected using verbal protocols, and researchers create visual representations that converge multiple solution paths for the purposes of validating the case solution. Case scenarios are built with medical staff and the case solution is uploaded to the server database, which can be uploaded by novices while solving problems with BioWorld. In doing so, instructors can design cases to be solved by groups of novices in the classroom, teaching on collaborative strategies that are critical in regulating the progress of groups and teams of problem-solvers. Recent advances in conceptualizing the context-specific nature of SRL, focusing on group collaboration, stands to better guide instruction (Järvelä & Hadwin, 2013; Volet, Vauras, Khosa, & Iiskala, 2013). Future research will evaluate the effects of adding new components to the BioWorld user model in terms of co-regulating processes involved in solving problems.

### **Supporting Self- and Co-Regulation in Intelligent Tutoring Systems to Help Students Acquire Better Learning Skills**

Ido Roll, University of British Columbia

Eliane Stampfer Wiese, Yanjin Long, Vincent Aleven, Kenneth R. Koedinger, Carnegie Mellon University

Providing scaffolding to help students regulate their learning has become an increasing focus within educational technologies, and specifically, within ITS. Overall, there is compelling evidence that scaffolding students' SRL can improve their learning gains (Aleven & Koedinger, 2002; Holmes, Park, Day, Bonn, & Roll, 2013; Wood and Wood, 1999). In this presentation we aim to extend the theory of SRL scaffolding in ITS by identifying three important developments in this area. First, we focus on the *objectives* of scaffolding. While domain learning remains an important objective, a more ambitious goal is to help students acquire better SRL skills and attitudes. Thus, the scope of the desired effect should extend beyond the supported environment and associated post-assessments to new learning situations. Second, we focus on the *role* of the scaffolding. Traditionally, the discussion around self regulation in ITS is framed either in terms of students' self-regulation (Winne, 1996), or external-regulation by the environment (Azevedo, Moos, Greene, Winters, & Cromley, 2008). However, learning in ITS can also be viewed as the emerging outcome of negotiations and interactions between learners and the system. We discuss this perspective in terms of co-regulation (Hadwin, Järvelä, & Miller, 2011), and investigate its implications on the design of regulatory scaffolding. Last, we discuss the *form* of the scaffolding, where we identify grounded feedback uses (Nathan, 1998; Stampfer & Koedinger, 2013) to implicitly encourage students to monitor their progress.

We ground the discussion on the objectives, roles, and form of SRL scaffolding by focusing on three important families of SRL strategies: Help seeking and help giving (Roll, Aleven, McLaren, & Koedinger, 2011; Walker, Rummel, & Koedinger, 2011); self assessment (Long & Aleven, 2013; Roll, Aleven, & Koedinger, 2011); and planning and monitoring (Holmes et al., 2013; Kinnebrew et al., 2013; Stampfer & Koedinger, 2012). In conclusion, we argue that these developments enable new modes of SRL support that could lead to sustained improvement in students' learning skills and attitudes.

### **From Domain Learning to Metacognitive Learning**

As mentioned above, several successful examples show that students who receive relevant support for their learning *processes* demonstrated better learning *outcomes*. However, can we aim higher than that? Can support for SRL achieve the ambitious goals of helping students learn to regulate their learning, and thus become more competent learners?

We previously proposed a hierarchy of goals for SRL scaffolding (Koedigner, Aleven, Baker, & Roll, 2009). Support for SRL should first help students apply better learning behaviours within the supported environment. Second, it should lead to better domain learning outcomes within the supported environment. Third, students should demonstrate better SRL behaviour in a future learning event without the SRL support. Last, the support should lead to improvement in future learning outcomes without the SRL support.

In recent years, several studies have looked at transfer of SRL behaviours, allowing us to evaluate characteristics of SRL support that seek to improve future learning. Roll et al. (2011) gave students adaptive feedback on their help-seeking actions in a geometry tutor. They found that students who received feedback transferred better help-seeking skills to new topics within the same environment, when no support was offered, but not to a new (paper) environment. Long & Aleven (2013) found a similar pattern. After each problem in an

ITS on linear equations, students were prompted to assess their understanding. While these students demonstrated more productive learning behaviours on subsequent problems within the tutored environment, they did not transfer their improved self-assessment behaviors to a new environment. Limited transfer of improved SRL behaviours was also found in environments that support planning and monitoring. In these environments, SRL support for some components of the task led to improved SRL on other, unsupported, elements, but so far failed to show significant improvement on SRL strategies in transfer topics, even within the same environments (Biswas et al., 2009; Holmes, 2013). Thus, while well-designed SRL support can lead to transferable results, the patterns of transfer across tasks, topics, and environments should be further examined.

### **From Self- to Co-Regulation**

To date, most efforts to scaffold SRL in ITS have focused on explicitly directing students to apply prescribed strategies, mainly through the use of static support. In such cases, regulation of learning could be considered Externally Regulated Learning (ERL; Azevedo et al., 2008), as the system chooses the sub goals and strategies for the student (e.g., using self-explanation prompts).

While the constructs of SRL and ERL are useful for discussing learning either from the student perspective (SRL) or the system perspective (ERL), they are somewhat less relevant when the regulation emerges from negotiations between the student and the system. A similar debate in regulation of groups sparked the idea of co-regulation (Hadwin et al., 2011). Here, we would like to extend the use of co-regulation to describe ITSs where the learning process emerges from negotiations and interactions between the learner and the environment. A good example for that process is the Open Learner Model (OLM; Long & Aleven, 2013; Zapata-Rivera & Greer, 2002). In OLMs, learners can view the ITS's estimation of their skills. Furthermore, several examples of OLM engage students in a discussion over desired goals and future activities. Another example is the work on peer tutoring (Walker et al., 2011). Rather than defining the interaction process for the student, the ITS offers strategies but does not impose them. The actual learning process is the result of contributions by the ITS and the two students who engage in the learning process. We argue that considering SRL support as a process of co-regulation can inform the design of support mechanisms that give more agency to learners and create stronger partnerships between ITS and the students.

### **From Explicit to Implicit Support**

While many theories of self-regulation emphasize monitoring and reflection as key components of learning, students often fail to engage in these processes. One reason may be the failure of many ITSs to provide meaningful opportunities for student reflection. For example, when asked to calculate standard deviation of certain data sets, or to add two fractions, how can students know whether their answers are correct? Grounded Feedback supports triangulation, as the student can recognize the correct or incorrect application of a to-be-learned skill by evaluating the system response in alternative, familiar representation (which could be situational, visual, or based on already mastered procedures; cf. Natahan, 1998). We demonstrate this process using two environments: a fraction-addition ITS that uses graphical representations to help students evaluate magnitude, and a data-analysis ITS which uses contrasting cases to give students a baseline with which they can make intuitive predictions.

While Grounded Feedback allows students to monitor their performance, recent classroom experiments suggest that this approach is met with only limited success (Stampfer & Koedinger, 2012). A more powerful support may combine Grounded Feedback with explicit feedback on students' use of that information to assess their performance. Such feedback follows an intelligent novice model, or "immediate + 1" feedback, as feedback is suppressed when students commit domain-level errors (giving them a chance to detect their own errors), and is given when students fail to use the grounded clues to successfully make sense of their domain-level mistakes (Mathan & Koedinger, 2005).

To summarize, we identify three developments in the landscape of SRL support in ITS. Put together, we believe that SRL scaffolding should aim for co-regulation by involving students in the pedagogical decisions, and giving students opportunities to monitor their progress. At the same time, the ITS should, like a skilled human tutor, intervene when students are off track. These directions could lead to SRL scaffolding that is more responsive to students' interactions with the environment, gives students more agency over their learning process, and subsequently, may lead to sustained gains to students' SRL skills and attitudes.

## **From the Classroom to Industry: The Push for Intelligently Guided Self-Regulated Training to Support Complex Skill Development**

Benjamin Goldberg, Robert Sottilare, U.S. Army Research Laboratory

The culture of education and training is quickly shifting. Technology is being utilized in the classroom more than ever, with new tools and methods completely reshaping how people interact with learning content and materials (i.e., interactive e-textbooks distributed to students on Apple iPads; Sloan, 2012). In turn, where

people learn is also rapidly changing. With enhanced mobile networks that support on-the-go internet access and the availability of advanced light-weight portable computers, someone can conceivably learn and train from anywhere in the world. This is leading to a culture based around the self-regulation of learning, especially within industries like medicine and the military that value continual on-the-job training for skill development. In this context, ITSs are being defined as major focal points in regulating interaction and instilling metacognitive skills to support future training opportunities (TRADOC, 2011). This is based on empirical evidence in the learning sciences community showing the benefit of training metacognitive strategies and their subsequent impact on future learning outcomes (Koedinger, Aleven, Roll, & Baker, 2009; Poitras, Lajoie, & Hong, 2012; Roll, Aleven, McLaren, & Koedinger, 2011). The challenge is overcoming barriers linked to authoring such systems (Sotilare, Goldberg, Brawner, & Holden, 2012). At the current moment, authoring systems that support SRL is time consuming and requires expertise. Can tools and methods be employed to streamline the authoring of environments that take into account metacognitive functions?

From this perspective, there are two fundamental problems that must be addressed. First, military and industry training domains are extremely volatile in nature, with continual changes in task procedures as the result of advancements in technologies and techniques. With a change in task execution, an effective ITS must be able to accommodate shifts in procedural knowledge so as to continue providing efficient performance assessment and feedback. This needs to be accomplished without completely overhauling a system to account for new domain information. Next, with the role of the instructor being redefined in a SRL culture, there is a large burden placed on the student to regulate their training experience. This requires planning, executing a set of actions, monitoring and assessing performance, recognizing error, troubleshooting potential solutions, and identifying cause and effect as it relates to the context of the experienced problem (Zimmerman & Campillo, 2003). Especially with tasks that evolve over time, focusing instruction to improve cognitive processes and promote higher-order thinking, rather than improve task-specific procedures, is needed.

As such, research is required to identify streamlined processes that produce ready to use ITSs that are metacognitively aware outside of the laboratory setting. To further deconstruct these challenges, the authors will provide a comprehensive overview of the current gaps in ITS authoring that must be addressed before training communities buy-in to adaptive training technologies. These include: (1) putting intelligent authoring tools in the hands of the instructor to create ITS-embedded training, (2) development of a systematic method of processes and standards to author such functions, and (3) providing sound pedagogical methods based on empirical evidence to enhance an individual's ability to regulate their own learning experience. These identified challenges will serve as the focal point of the discussion, where we examine current work surrounding authoring issues linked to SRL in post-academic training spaces and the role metacognition plays in pedagogical planning.

## **The Generalized Intelligent Framework for Tutoring (GIFT): Putting Authoring in the Hands of the Instructors**

Authoring ITSs to aid in metacognitive development across training-based industries is a challenge that must be addressed. Training environments for military and industry relevant domains are often drastically different from the academic settings ITSs are typically applied within. Much of the training in job-related instances focuses on specific tasks and procedures that require proficiency before they can be fully conducted under proper operational contexts. In addition, how tasks are conducted depend largely on context, which is often ill-defined in nature. Thus, performing a task under one context may differ greatly from performing the same task under a different set of conditions. Therefore, a focus of instruction needs to be based on developing strategies to improve how individuals monitor performance, troubleshoot complications, and regulate attentional resources, rather than solely on executing task procedures. This will improve an individual's ability to self-regulate their future learning, as well improve how they conduct and adapt procedures based on reflections of actions taken.

The current issue is that building ITSs is expensive, labor intensive, and requires expertise across a number of disciplines (Murray, 1999; Sotilare, Goldberg, & Durlach, 2011). They are also commonly built as stand-alone solutions to a specific program, offering minimal reuse for future applications. Tools need to be developed that address these gaps and enable instructors to build and modify ITS model components that can be plugged into any training application available. This requires standardized methods and processes to build tutors from, along with an intelligently guided authoring process to assist instructors in building core components. Existing tools are available for standardized authoring of ITSs linked to cognitive example-tracing and constraint-based modeling techniques. These include Carnegie Mellon's Cognitive Tutor Authoring Tools (CTAT; Aleven, McLaren, Sewall, & Koedinger, 2006) and University of Canterbury's ASPIRE Authoring Tool (Mitrovic et al., 2008). They provide a generalized authoring environment, but lack elements linked to interactive simulation-based training systems such as gaming platforms commonly used in industry training.

The U.S. Army Research Laboratory (ARL) is currently addressing this problem. ARL is in the process of developing the Generalized Intelligent Framework for Tutoring (GIFT), an open source domain-independent architecture that provides standardized approaches for authoring, delivering, and evaluating ITS components and functions (Sotilare et al., 2012). Essentially, GIFT is a set of tools and standards used to author ITS

solutions to promote and accelerate learning, regardless of the task being trained (Sottilare & Goldberg, 2013). What GIFT provides is a modular approach to ITS development, enabling a swap and play capability, which promotes reuse of standardized modeling techniques designed to accommodate any instructional domain. Where GIFT needs to shine is in compensating for the expertise and knowledge a particular author or instructor lacks. This requires tools that aid an author in modeling a domain to the parameters set forth by GIFT standards, developing assessments and triggers associated with the modeled domain, and identifying instructional strategies to utilize when triggers are activated.

The caveat is that all of these processes need to be defined in a generalized fashion so that they extend across domain implementations. Currently, GIFT monitors performance through an ontological representation of a domain by expressing objectives and concepts in a relational hierarchy. For each concept identified in the hierarchy, an assessment is authored that designates metrics linked to competency. These metrics are used to produce a learner state for each defined concept, which is used by the pedagogical model to inform guidance functions. From there, GIFT makes informed pedagogical recommendations on a domain-independent level (e.g., provide hint, provide prompt), leaving it to the instructor to author that strategy as an actionable tactic (Goldberg, Brawner, Sottilare, et al., 2012). In this instance, a developer authors multiple levels of tactics enabling the system to vary the level of detail provided in feedback messages based on individual differences associated with a learner. In the event that a system requires updates to task procedures, tactic definitions for each affected concept will need to be updated. This can be a taxing process on the course administrator if the task is modified on a regular basis. The same process can be said for supporting metacognitive tutoring. SRL behaviors require representation in GIFT's domain model that enables tracking of user interaction. This allows building rules to determine proper and improper execution. The goal would be to support the methods described above from the various authors. These determinations are used by the pedagogical model to enact a designated intervention; however, where metacognitive prompts differ is in their representation. They can be represented as standardized prompts that can be maintained across domains, without required edits.

## Metacognition and Domain-Independency

As described above, GIFT works with system authors by providing instructional strategy recommendations, which are then translated into tactics as they relate to the training context. These tactics are used during ITS runtime and are selected based on a learner's individual differences. At the current moment, feedback in GIFT is domain dependent and requires explicit content linked to each concept modeled. When it comes to metacognitive feedback, what are the implications to a domain-independent approach? First, modeling techniques, such as the one presented in Biswas et al.'s paper, need to be developed to monitor an individual's practice of metacognitive strategies that can be expressed in a generalized format. Another example would be incorporating a help-seeking model, as highlighted in Koedinger et al. (2009). Researching and establishing models based around commonly available GIFT interactions (e.g., request hint button) can be used to build theoretical representations of how effective students use the interface to solve problems and troubleshoot errors. Depending on the domain, an assessment model will need to be generated that associates cognitive and metacognitive processes with task execution. This can be used to establish an assessment model for detecting learners exhibiting poor metacognitive behaviors, and is used to trigger feedback interventions to improve subsequent behavior. With support for applying varying modeling techniques, generic tactics can be identified that are based around effective metacognitive behavior, and should be based around learning theory identified by Roll et al. and Lajoie & Poitras. While tactics can be represented in a domain independent format, monitoring how a learner adapts their behaviors as a result of the intervention is an open question, and is dependent on the modeling approaches being applied.

In summary, we identify the desire from military and industry-based training communities to incorporate technologies to enable SRL. With technology being utilized more than ever for this purpose, using ITSs to monitor and improve metacognitive behaviors can greatly enhance the learning. To streamline this development, authoring needs to be taken out of the lab and put in the hands of those using the tools.

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## Acknowledgments

- (Paper 1): This work was supported by NSF-IIS Award #0904387 and IES CASL Award #R305A120186.
- (Paper 2): This work was supported by the Social Sciences and Humanities Research Council of Canada LEADS Research Partnership grant, the Tier 1 Canadian Research Chair in Advanced Technologies for Learning in Authentic Settings, the Canadian Foundation for Innovation, and by McGill University.
- (Paper 3): This work was supported by the Pittsburgh Science of Learning Center, through the National Science Foundation (#SBE-0836012), the University of British Columbia through the Carl Wieman Science Education Initiative. and a Graduate Training Grant awarded to Carnegie Mellon University by the Department of Education (# R305B090023).

# **History Learning and Teaching Today: Learning What? Becoming What? By What Practice?**

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**Abstract:** History is intimately connected with personal and collective processes of becoming. It is also a field of contest among curriculum-makers, teachers, parents and scholars over who and what children will be; and this contest has greater consequences as our world grows more crowded and more connected. School curriculum-makers and teachers have never had a monopoly on what children learned about the past; but today, the Internet makes encounters with differing historical narratives ever more common. In this symposium, scholars from three countries (Israel, Canada and the United States) will come together around a collection of unique studies addressing the question of how teachers can be better prepared to help their students navigate the increasing challenges of learning and becoming in today's increasingly globalized and internetworked world.

## **Introduction**

History is intimately connected with personal processes of becoming, wherever and whenever one lives. As MacMillan (2008) writes, "For all of us, the powerful and the weak alike, history helps to define and validate us." (p 57) In view of the power that history has to shape who we become (individually and collectively), developed nations and states throughout the past century have diligently crafted their history curricula to shape the identities and loyalties of their citizenry (Loewen 1995; Coles 2000). At the same time, parents, teachers and peers often promote different accounts of students' past than schools do, perhaps ones more allied to ethnic and class identities (Coles 2000). Finally, amidst this competition over students' identities, academic historians and history educators have worked to establish and reinforce a place for the unique epistemic practices of their discipline in students' understanding of the past (Kuhn et al., 1994; Wineburg, 1999; Seixas 2000).

Thus, history education must be viewed as a field in which learning and becoming are very much at issue, and very much contested. This contest has greater consequences as our world grows more crowded and more connected, because the differences among these contesting claims to the understanding of the past become more pressing. Life in a globalized and internetworked world involves increasingly frequent encounters with "others" whose values, culture, and narratives of the past may differ from ours. Such encounters may both exacerbate conflict and present potential for learning. In many western nations, the idea of global awareness and its importance in the core curriculum is being asserted (e.g. p21.org), but achieving this goal is nontrivial, and may be incompatible with the most common practices of textbook-driven history teaching. What is certain is that teachers of history must in some way be ready to recognize and address the inevitable conflicts and disjunctions among the accounts of the past that enter their classrooms, and perhaps take advantage of the pedagogical potential they provide.

Our symposium draws together scholars from three countries and various disciplinary perspectives to examine what students and teachers of history are learning, what they are becoming, and by means of what practices. The first two presentations address the possibilities and challenges involved in integrating historians' epistemic practices into instruction. Fogo's study examines the practices that expert history teachers and teacher educators promote to address the challenges of teaching history discussed earlier. He conducted a Delphi study involving three rounds of ratings, comments, and suggestions made by a panel of 26 expert history educators across the United States. These resulted in a list of nine core teaching practices that the respondents suggested a skilled history teacher must master. The Delphi panel attained an uncommonly high degree of consensus around this set of practices, which are nonetheless uncommon in history teaching today.

The second study, by O'Neill, D'Amico and Guloy, examines how more typical practices of history teaching shape students' understandings of historians' practices, with particular emphasis on why they construct differing accounts of the past. The study examines a series of in-depth interviews with five practicing historians and seven secondary students in western Canada, which focused specifically on why historical accounts may differ. Prompted by a series of survey questions that they answered and explained aloud, students stressed the

social functions of history and what they believed historians *should* do, such as reinforce national identity by getting to the truth of things. For their part, historians interrogated what it means for students to hold a “sophisticated” understanding of the discipline. For historians in some specializations the pursuit of an ultimate truth was considered quite naïve and a sign of inadequate education; but others saw this view as legitimate depending on the context. Overall, the study puts into relief how typical practices of history teaching lead to simplifications of historians’ varying epistemologies and practices.

Our final two presentations provide models of how integrating historians’ practices curricular interventions can prove fruitful in addressing the challenges and possibilities of learning and becoming in the context of a deeply entrenched historical conflict. Both studies took place in Israel, a bi-national country in which Jewish and Arab children are educated in separate schools but follow the same national curriculum. The research of Ben-David Kolikant and Pollack revolves around a dialogically-oriented curricular intervention involving pairs of Jewish-Israeli and Arab-Israeli youth working together online to examine historical events pertaining to the Israeli-Palestinian conflict. Goldberg’s research takes place in the same national context, but examines the effects of a quasi-experimental intervention in which one group of students received a curriculum involving conflicting sources that was oriented toward historians’ disciplinary practice. A comparison group instead studied an exam-oriented textbook excerpt. Both studies highlight the feasibility of incorporating historical thinking into the classroom and shed light on learning processes in these classrooms.

After a short (5 minute) introduction, each set of presenters will be given 10 minutes to overview their work for the audience as a whole. Then, each group of presenters will take one corner of the room to meet and dialogue with interested participants for 15 minutes on the question of whether, or in what ways the “disciplinary practice” approach to history teaching is at odds with an approach that stresses students becoming loyal participants in a national collective. For the following 15 minutes, participants will return to their seats and our discussant will lead a whole-group discussion about the challenges and possibilities of learning and becoming in relation to history. Finally, our discussant will have 10 minutes to make her own closing remarks.

## Defining Core Instructional Practices for Teaching History

Brad Fogo, Stanford University

Educational researchers call for identifying effective teaching practices to inform and improve pre and in-service teacher education. Researchers have focused on teaching practices across grade levels and subjects, and use different vocabulary for identifying effective practice. For example, Ball and Forzani (2009) have detailed several “high leverage” teaching practices; Kazemi, Franke, and Lampert (2009) focus on “high quality” “instructional strategies;” and Grossman, Hammernes, & McDonald (2009) describe “core” practices.

The new core practice research work has largely overlooked history-social studies. This is not to suggest a poverty of research on the teaching of history. Rather, the field has grown steadily over the past three decades. Researchers have identified different types of teacher knowledge (Evans, 1990; McDiarmid, 1994; Yeager & Davis, 1995), crafted portraits of good history teachers (Bain, 2006; Brophy & VanSledright, 1997; VanSledright, 2011), described “ambitious” and “authentic” history teaching (Grant & Gradwell, 2010; Saye et al., 2013), and examined the impact of accountability policies on elementary and secondary history instruction (Grant, 2006). Much of this work, however, revolves around small case studies of teachers, and, as noted by Wilson (2001), does not focus squarely on the links between teaching and learning. The empirical base connecting teaching with learning history remains thin.

My research focuses on the following questions: Is there a set of core instructional practices for teaching history? If so, what are they? What teaching practices impact students’ ability to engage in historical analysis and understand the major explanatory accounts and concepts of history? Here, I discuss findings from a Delphi panel survey of 26 expert history educators - teachers, teacher educators, and educational researchers - focused on developing consensus around a set of core teaching practices for secondary, history education (Fogo, 2014). Researchers have used Delphi surveys across the social sciences to facilitate expert group work for decades. The approach involves multiple rounds of survey analysis to develop group consensus around specific issues and decisions (Clayton, 1997). Participants are selected in respect to their expertise on topics under consideration, and remain anonymous throughout the process.

I sought to draw from the expertise of three groups of history educators in this study: master high school history teachers, history teacher educators, and leading researchers in the field of history education. Eleven teachers and 15 teacher educators/educational researchers were recruited for the panel. Criteria for teachers focused on creating a diverse, national sample of award winning teachers with extensive experience teaching secondary American and world history courses. I selected teacher educators and researchers from university-based education, history, and teacher education programs. They were identified as leaders in the field through their research and teaching experience.

This study used an on-line survey format. Each round of the survey consisted of two parts. In part one, participants rated titles and short descriptions of teaching practices on a 5-point Likert scale indicating whether

they thought the practice should be considered core (1=strongly disagree; 5=strongly agree). Core teaching practices were defined as the “instructional repertoire (strategies, routines, and moves) teachers enact that have great potential to impact students’ ability to engage in historical analysis and understand the major explanatory accounts and concepts of history.” Participants provided justifications for each rating and suggestions for revising titles and descriptions. In part two of the survey, participants generated additional core practices. They were asked to include a practice title and description, along with a justification for the practice. Participants repeated this process of rating, commenting upon, and suggesting practices across three survey rounds. The final round of the survey included a third section where participants selected practices they considered most important for effective history teaching, for pre-service teacher education, and for in-service professional development.

Analysis of data between rounds included compiling a rank ordered list of the teaching practices based upon average ratings, modes, and standard deviations. Additionally a one-way analysis of variance (ANOVA) was conducted to identify possible differences between the responses of teachers and teacher educators/researchers after each round. Suggested practices were coded and grouped by emergent themes. New practices were crafted for practices suggested by multiple participants. Between rounds, participants received summaries of ratings, comments, and suggestions, along with explanations of edits and additions made to practice titles and descriptions.

In round one, participants rated and commented on 10 practices. Each practice included a title and one to two sentence descriptions. Practices were crafted from the literature and intended to reflect both ambitious and more traditional teaching. Three of the initial practices were dropped for round two and eight new practices were added based upon the ratings and suggestions of panelists. In round two of the survey, participants rated and commented on 15 teaching practices. These practices were consolidated into 12 practices for round three.

After three rounds of the survey, strong consensus developed around nine practices:

- Use Historical Questions
- Select and Adapt Historical Sources
- Explain and Connect Historical Content
- Model and Support Historical Reading Skills
- Employ Historical Evidence
- Use Historical Concepts
- Facilitate Discussion of Historical Topics
- Model and Support Historical Writing
- Assess Student Thinking about History

The final average rating for these nine practice titles and their descriptions was 4.85 out of 5.00. For seven of these practices, ratings steadily increased and standard deviations decreased with revision, development, and consolidation across rounds.

In stark contrast to many group efforts focused on making history education decisions, this Delphi panel offered consistently constructive feedback and suggestions along with increasing amounts of agreement across rounds. The work of this panel is also unique in providing empirically based warrants for a coherent set of teaching practices that together represent a disciplinary, inquiry-based approach to teaching and learning history. Each of the practices crafted in this study can be further elaborated and validated. Nonetheless, as portraits of instructional practice, they can help teachers, teacher educators, and professional development providers plan, implement, and reflect upon ambitious, authentic history teaching. Moving forward, the results of this survey might also help focus study designs and assessment measures to examine the development of teacher practice and how these history teaching practices, or combinations of them, relate to students’ learning of prescribed textbook accounts, understanding of historians’ research practices, and understanding of themselves as historical thinkers and actors.

## **High School Students’ and Historians’ Ideas about Practices of Historical Storytelling**

D. Kevin O'Neill, Laura D'Amico and Sheryl Guloy, Simon Fraser University

As Fogo discusses, ambitious history teaching aims to engage students in some of the disciplinary practices of historians, such as reasoning with primary-source evidence and writing accounts of the past. However these practices may make little sense to students who hold assumptions about historical accounts that are inconsistent with those of historians. For example, it is common for students to speak and act as if a historical account can tell exactly what happened in the past. Many historians consider this a naïve view, since any story must inevitably attend to some details and exclude others. A narrative must be selective; it simply cannot capture everything that happened. Students who expect a historical account to be a copy of the past will be left “helplessly shrugging their shoulders in the face of competing stories” (Lee & Shemilt 2004, p. 31) if their teachers ask them to examine sources without first addressing the reasons why historical accounts may differ.

We conducted in-depth interviews with five practicing historians and seven secondary school students about why historians tell different stories about the past. The data were collected during validation of an online survey that will enable teachers to quickly assess the epistemological assumptions about history that their students bring into class, and how these change through instruction (O'Neill, Guloy, and Sensoy in press). One question runs as follows:

If a historian is learning about the events of a period and finds two stories about them that disagree, what should she do? Rate each statement from 1 to 5 (1=strongly disagree, 5=strongly agree):

- She should ignore both stories. It does not make sense for historians to disagree
- Try to figure out which author is less biased or was closer to the events, and use only that one
- Make an educated guess about what most likely happened, based on other evidence
- Learn about the authors and try to understand how they looked at and felt about the events

Our survey questions were informed by a popular theory which aims to describe the increasingly sophisticated ideas that students develop as they understand more about the nature of historians' research (Shemilt 1987). Shemilt's theory describes four discrete stages though which students progress, given appropriate learning experiences. Beginning with a naïve view that it is unproblematic for historians to know what happened, students can develop an appreciation that author bias and incomplete evidence produce important methodological challenges for them. At the apex of development, according to the theory, is the view that while bias and limited evidence are important, historians' accounts may also differ simply because they seek to answer different questions.

In addition to being useful in refining our survey instrument, the validation interviews provided a rare opportunity to examine and contrast how historians and students reacted to the theory embodied in it. In their interviews, our 5 historians (all tenure-track history professors whose specialties varied widely, including Latin American and Middle Eastern history) were asked to check whether the survey questions adequately reflected Shemilt's 4-stage theory. In explaining their judgments and offering refinements to the questions, the historians also reflected on the adequacy of the theory in describing their colleagues' practices, as well as the challenges they face in helping students understand and engage in those practices. On one hand, Shemilt's theory was seen to fit well with ideas that the historians recognized among their students, and even their colleagues:

Interviewer: Do you identify any of these statements with students that you are teaching or have taught?

Historian 5: Oh yeah! Oh yeah. In fact I have colleagues who are still at stages 1 and 2.  
Honestly.

On the other hand, historians identified several ways in which the theory's valuation of the most "sophisticated" understanding of historians' work was problematic. One interviewee (Historian 1) whose work focuses on 20<sup>th</sup>-century America, suggested that the time period under study was important to what one considers sophisticated, stating "it's probably more challenging for the medievalists to get the students to understand even that there *is* a historical debate." Another historian who studies Latin America identified social status as an important element in shaping people's sophistication with regard to varying historical accounts:

Historian 3: If you want to know about...the problems of perspective and truth and formal systems of understanding—talk to a Latin American woman. Or an indigenous person. They have a sophisticated understanding of account to the past and accounts of truth, that it is about the position that they occupy in society.

Finally, an interviewee who specialized in Middle East history suggested:

Historian 5: Particularly when it comes to...controversial subject matter, the notion that what you're teaching is in some fundamental way "true" becomes very important for many people.... There is something [bad] that happened, and as long as we get to the truth of what happened, then we can solve all these problems.

Our 7 high school students represented a wide range of academic ability and included recent immigrants. Recruited with the help of their teacher, they were asked to complete our survey while thinking aloud. Unsurprisingly, the high school students did not know enough about the varying specializations in history to see how a historian's specialization or audience might influence the value that is placed on different explanations of differing accounts. Students' ideas were instead largely shaped by their understandings of the unifying social function of history as taught in school (as discussed below by Goldberg). As they explained their

answers to us, their ideas about what historians do and *should* do came out clearly. Student 6 stated, “Some people can say really stupid things about what happened, and they know it’s not true, and the historian tries to see which one is actually the most proper story.” This and other answers stressed the importance of historians’ contribution to a national dialogue by “setting the story straight.”

Students also viewed historians’ accounts as identifying the mistakes that have been made in the past, in order to correct or avoid them in the future with improved laws and policies:

Student 2: I think historians are the people who try to improve our society by looking at what people did beforehand. And instead of more like interpreting that, they also try to use that to improve our society.

Straightening out competing stories, or getting “the whole story” by working methodically with a wide range of evidence and testimony, was viewed by the students as important for social cohesion:

Student 3: They should look more and find more evidence to make sure that evidence is true. So the citizens can know the true story.... Let’s say [some people claim] that it was their great, great, great grandfathers that made this place. Other people could say [the same thing] and they could get into a fight. And it could be a bad situation.

This view of the historian as a national or international referee (a role that many historians would disavow) may have been influenced by the nature of the social studies curriculum in our setting, which emphasizes diversity and inclusion. But as one of our historians reminded us, the nature of formal education itself can encourage a naïve view of historians’ practices:

Historian 3: Students struggle with...the idea of multiple, viable accounts [because] they’re in a class. They figure if they get the authoritative account, they’ll do well on the test.

All of these voices, students’ and historians’ together, prompt us to suggest that there is not a single pinnacle of historians’ practices that we can agree upon and initiate students into. Rather than viewing a learner’s understanding of historical research practices as developing along a single, linear scale as Shemilt conceived it (and which many history educators seem to accept), a better way to represent them may be as an interrelated system of beliefs, similar to what Schommer-Aikins (2004) has developed for more generic epistemological beliefs. Such a multidimensional way of understanding what students are learning about historians’ practices will be more able to accommodate the fact that the values historians (and teachers) associate with different epistemic practices are subject to a variety of competing contextual influences. This is the understanding that we are bringing to the design of our online survey, [www.historyconcepts.org](http://www.historyconcepts.org), which we hope will become a useful tool for history teachers at both the secondary and postsecondary levels.

## Becoming Dialogical through Internally Persuasive Discourse with a Conflicting Other

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As discussed in our introduction, encounters with Others can potentially broaden people’s horizons and enrich their experiences; but they can also pose conflicts and cause people to become entrenched in the local and the familiar (Hermans & Dimaggio, 2007). In such a reality, dialogicality becomes an important asset. School can educate students to become part of a more plural society by enhancing students’ ability and willingness to perceive, recognize, and deal with differences, conflicts, and opposition, and to arrive at workable solutions (Hermans & Dimaggio, 2007). Ideally, schools can facilitate students in exploiting the learning potential of these encounters. Specifically, the availability of myriad voices can serve as an opportunity for people to critically reflect on what they know (or think they know) in light of alternative viewpoints and the differing perspectives of others.

## Internally Persuasive Discourse and the Doing History Together Project

The *Doing History Together* project (funded by the Israeli Science Foundation (ISF grant number 1236/09)) was launched as part of such an endeavor. In this project, students from opposite sides of a bi-national conflict collaboratively e-investigate a historical event from their in-groups’ shared troubled past. Our instructional model was inspired by Bakhtin’s (1981) dialogic stance, which states that our entire population exists in a continuous dialogue with the surrounding world. Bakhtin (1981) distinguished between two types of discourse:

*authoritative discourse* (AD) and *internally persuasive discourse* (IPD). In AD, utterances and their meaning are not negotiable, let alone modifiable, when interacting with another voice; rather, such discourse requires unconditional alliances (Wertsch, 1991). History education in many countries nurtures AD, by teaching national narratives such as truth and encouraging critical thinking, for example, by setting evaluation on multiple choice information-focused questions (Pingel, 2008).

In contrast, our model is aimed at provoking and encouraging students to critically examine their ontological truth—ideas, viewpoint, knowledge, beliefs, concerns and so forth—in light of alternatives presented by an Other, an interlocutor whose own ontological truth may differ and perhaps even be contradictory. Such a discourse is termed IPD by Bakhtin. The main role of the peer in our model is not to enable the group to achieve a joint goal, but rather, to create a dialogic agency in each other. We share Matusov's (2009) view that such a process can bring participants “to transcend their ontological circumstances” (ibid., p. 208), and become aware of the cultural bias associated with what they know or think they know as well as to be more tolerant of other viewpoints, even if they conflict with their own -- which might mitigate tensions within a diverse society.

We decided to test these ideas in history classes because history can serve as a powerful venue to establish IPD, given its multiplicity and interpretive nature (e.g., Seixas, 1993; Seixas and Peck, 2004; Wineburg, 2001). Historiography can be described as navigation among conflicting voices and languages (involving, *inter alia*, the voices of those who lived in the past, and the voices of other historians, cf. Wertsch, 1991). In other words, historiography is about IPD.

The activities emphasized multi-perspectivity. The students were given primary and secondary sources that all together presented multiple perspectives regarding the event and were asked to read the sources and compose accounts of the event, first in ethnically homogenous pairs and then in bi-ethical quartets, comprising two pairs. The activity took place in a Wiki-like environment. Specifically, after uploading their essays to the wiki, each pair was asked to read and comment on the Other pair's essay, and then the foursomes (comprised of the two pairs) were instructed to collaboratively produce a joint essay, which could either contain one account agreed upon by all peers, or two (or more) answers followed by an analysis of the nature of the disagreement between them. To this end, the two pairs first communicated through the Wiki environment asynchronously, and after about two weeks through a 90-minute synchronous textual e-discussion.

## **The Study**

In order to gain insights on the learning outcomes as well as on the learning processes that took place within the context of the activity, we investigated two enactments of the DHT model in Israel, in which 52 Israeli Jewish and 52 Israeli Arab/Palestinian students from 4 schools investigated events from the Israeli-Palestinian conflict's past. Enactment 1 concerned the issuance of Churchill's White paper (1922) issued by the British in face of the growing tension in the area, and enactment 2 concerned the issuance of the UNSCOP report, in 1947, in which the partition plan to divide the territory into two states was recommended and later accepted by the UN. Our main data sources were the essays (of the pairs and the foursome) as well as the transcripts of the textual e-discussions.

## **The Collaboration Process: From Authoritative Discourse to IPD**

Thematic analysis of the pair essays reflected that the participants had employed an AD on the topic. Specifically, participants chose to include themes that were aligned with their in-group narrative and ignore those that did not. Themes that were common in the answers of Arab participants did not appear in the answers of the Jewish participants and vice versa. Such behavior is in line with the literature (Bar-tal & Salomon, 2006; Wertsch, 1998, 2000). This brought about two dichotomous interpretations of the event. Specifically, in the relational triangle among the British, Jewish, and Arab historical agents described by the Arab participants, the British historical agent supports the version of the Jewish agent at the expense of the Arab agent, who is discriminated against and whose rights are violated. In contrast, the Jewish participants described a relational triangle in which the British historical agent acts in an even-handed manner toward the Jewish and Arab historical agents.

Interestingly, however, although the participants were given an opportunity to write separate summaries, 58% of them produced joint essays that included one account apparently acceptable or tolerable for all four peers. We termed these joint texts *mosaics* because in their production the students used themes (or metaphorically, “bricks”) taken from the two pairs’ essays and interwove them into one joint account. These mosaics did not contradict either of the in-group historical (meta-)narratives. Namely, there was no evidence that the participants abandoned their in-group narratives. However, the joint accounts reflected improved perceptions of the historical agents, the constraints under which these agents operated, their interrelations, and an attribution of responsibility for the events to the historical agents in their own in-group as well. These accounts implied that IPD did occur among these participants. However, they transcended their one-dimensional

perception stemming from the homogeneous stage. The remaining 42% of the foursomes did not produce a joint essay, but rather, uploaded one or two of the pairs' essays, sometimes after it had been edited.

In order to shed light on the process by which these mosaics were produced as well as to better understand what impeded the production of joint essays in the other foursome, a discourse analysis was conducted on the transcripts' e-discussions of the foursome.

Except for two e-discussions in which one side expressed a muffled voice as if attempting to avoid a confrontation, all e-discussions were lively and collaborative. The historical discussions were for the most part disputatious. The most common collaboration process (found among 14 e-discussions) included three discursive stages. In Stage 1, the discussion was characterized by participants' parallel adoption of an AD-like interaction style, with participants getting their wires crossed. Each pair in the discussion viewed their opinion as the truth, which they must convey or explain to the other pair, who does not know or understand it. Apparently the participants continued the same AD that was expressed in their pair essays.

In Stage 2 the limits of the own viewpoints became apparent to the participants. Consequently, each tried to make his own voice approachable to the Other, by initiating a discussion on the meaning of ideas. In this phase, a two-sided examination of the event took place in a distributive manner. Participants examined their argument in light of "hits" by the Other: the flaws the Other detects in the argument and the alternatives he or she provides.

Finally, in Stage 3 fission occurred. We borrowed this term from the field of physics, where it denotes a process in which an atom's structure becomes unstable as a result of a hit by an external neutron. In our metaphor, we envision "cracks" forming in one's narrative, one's truth, hitherto primarily shaped by surrounding in-group narratives as the Other arguments "hit" it. Fissions are those moments when the familiar and up-to-that-moment reasonable truth is seriously re-examined. In these e-discussions IPD occurs.

Usually (13 out of the 14 e-discussions) this stage was followed by an organizational episode, in which one side suggested a mosaic-like text segment for the joint account that took into consideration the Other's perceptive. Usually, this text was accepted by the Other peers. Two other mosaics were constructed by a process resembling that described extensively in the literature, for example, by Roschelle and Teasley (1992), whereby the group's mutual engagement is around a shared goal. The remaining 8 e-discussions were characterized by cycles of dispute (resembling stage 1), in which no collaborative elaboration took place. These e-discussions resulted in zero joint essays.

In light of the above, we can view all the mosaic-like essays as products of elaborative e-discussions. Although they align with both in-group narratives, they do not represent an offhanded compromise, but rather a change in students' discourse from AD to IPD. Through these e-discussions students had an opportunity to re-examine their truths in light of alternative truths presented by another, and as they learned the limitations of their voices, and witnessed the tenability of the Other's voice to their "attacks," they became more tolerant of the existence of Other, conflicting voices, thus allowing them to co-exist in their joint essays. These mosaics thus represent a more multi-faceted understanding of the historical events studied, gained through IPD. These findings strengthen our belief that continuous participation in dialogic activities such as in the doing-history-together project will encourage and facilitate students to become more dialogical, more respectful of diverse opinions, and thereby facilitate a plural, tolerant society.

## Becoming a Dialogical Illocutor through Disciplinary Practice

Tsafrir Goldberg, University of Haifa

The field of history education has witnessed some vociferous controversies about the feasibility and desirability of attempting to engage students in historical critical thinking practices. Of particular relevance to this symposium, scholars have questioned whether students can become both "little historians," analyzing sources and meta-narratives critically, and loyal members of their collective at the same time (Linenthal & Englehardt, 1996; Naveh & Yogeved, 2002; Shemilt, 2000). This question is echoed in the contribution of O'Neill, D'Amico and Guloy above.

The issue of engagement with conflicting meta-narratives has also been at the center of attention in peace education. In the last decade it was claimed that historical narratives serve to legitimize and prolong inter-group conflicts (Bar-Tal & Salomon, 2006). Generally, collectives tend to promulgate an authoritative self-justifying historical narrative through commemoration and history teaching, which tends to ignore or denigrate out-group perspectives (Ferro, 1984). It is assumed that engagement with and acknowledgement of out-group narrative would lead to better intergroup dialogue (Bar-On & Adwan, 2006). Thus it appears that historical sense making practices such as critical analysis of conflicting accounts may serve not just in induction into the community of practice, but also in bridging between conflicting collective identities (McCullly, 2010).

Thus for example, Barton and McCullly (2010) reported the evolving Internally Persuasive Discourse among adolescents in Northern Ireland while engaged in disciplinary critical inquiry of the Protestant and Catholic historical perspective. Ben-David Kolikant and Pollack report similar development in an Israeli

context. However, most of the writing on this potential outcome remains theoretical or anecdotal. Hardly any of the writing on the topic used empirical methods or compared effects to those of conventional history teaching or to a control group.

To fill this gap, a study in a quasi-experimental random allocation design compared the effects of studying a conventional, authoritative textbook history of the Jewish Arab conflict with the effects of engaging in critical disciplinary practices with sources on the topic. Israeli-Palestinian and Israeli-Jewish adolescents were randomly allocated to one of the two learning conditions, in which they individually studied the causes of the 1948 Jewish-Arab War and the birth of the Palestinian refugee problem. Prior to and following the learning intervention they wrote essays representing their perception of the topic, and filled questionnaires regarding in-group identification and interest in out-group. Compositions were analyzed to track socio-cognitive bias, responsibility attribution and argumentative structure.

Two weeks later participants proceeded to engage in bi-national small group conversations about the historical topic and about possible solutions to the problem. Discussions were recorded, transcribed and analyzed for discussion style and joint decision-making, which were compared between the two learning conditions and with those of a control group.

Analysis of individual written work showed a marginally significant difference in the frequency of social cognition bias between learning conditions. The Conventional learning condition presented a higher frequency of attribution bias compared to the Critical Disciplinary condition. There was no significant difference between the learning conditions in argumentative structure or attribution of responsibility.

Analysis of bi-national discussions showed a significant difference between the learning conditions in social domination and in the frequency of joint decision-making. The conventional authoritative learning condition featured a higher frequency of domination by the Jewish participants and a lower frequency of joint decisions about the historical topic and about the future than both the critical disciplinary condition and the control. It also appears that Jewish participants in the critical disciplinary condition presented a more evaluative epistemic stance towards sources than participants in the conventional condition, aligning with the higher conceptualization of historian's practice by adolescents reported in O'Neill's study.

These findings taken as a whole may be interpreted to imply that engagement in disciplinary practice promoted learners' "disciplinary" identity to a certain degree, as indicated by lower socio-cognitive bias and evaluative-epistemic stance. It may be that such an engagement in community of practice can explain the more collaborative and rational bi-national dialogues (Driver et al, 2000). This interpretation appears to be aligned with Ben-David Kolikant & Pollack's findings about the relation between engagement in practice and dialogicality. Thus it seems that becoming a more dialogic inter-community illocutor may have been achieved through engaging in disciplinary practice or becoming a member in a disciplinary community. By contrast, it seems that conventional history teaching may impede both engagement in disciplinary community and in cross community negotiation.

## Implications

The contributions to this symposium address in different ways the challenges that students face in doing the difficult identity work that a diverse, connected global society requires of them. Previous research suggests that schools, teachers and parents often make demands that emphasize students becoming loyal members of national or regional groups, ethnic groups or classes, and/or academic high-achievers. At times, these demands can grate against the extra-national disciplinary norms that history education scholars and master history teachers would prefer to emphasize. Fogo's work reveals a strong consensus among the participants in his Delphi study regarding the place that historical research practices should have in history classrooms. However, the nine core practices he lists are anything but common in many history classrooms today, partly because many teachers (at least in the U.S. and Canada) have little background in the discipline of history (Ravitch 2000). O'Neill, D'Amico and Guloy's research sheds light on the gulf of understanding that this state of affairs creates between academic historians and students in mainstream high school history classes. However, the contributions of Goldberg and Ben-David Kolikant and Pollack provide evidence that creative pedagogical designs that emphasize disciplinary norms can succeed in better equipping students to navigate claims to their loyalty and identity - even under circumstances of deeply entrenched historical conflict.

We hope the unique plan we have in place for organizing our session, together with the participation of our discussant and co-facilitator Abby Reisman will enable conference attendees to participate with us in developing a better understanding of the challenges and opportunities of learning and becoming that school history presents.

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## **Learning and Thinking in Practice: Complex Systems Thinking “In the Wild”**

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**Abstract:** Research in the field of learning sciences demonstrates that various forms of knowledge are created through participation in diverse but often undervalued community practices (Nasir, Rosebery, Warren, & Lee, 2006). However, knowledge created in practice is not traditionally explored in research about complex systems thinking (Duarte Olson, Forthcoming). This session seeks to recognize and capitalize on the wealth of complex systems knowledge learned through everyday practices in informal contexts. We present arguments that are grounded in research taking place in four different communities—with Brazilian samba schools, triathletes, Native Americans, and environmental educators. The goal of the symposium is to discuss (1) how complex systems thinking can be developed through different practices in informal environments, and (2) how an under-representation of diverse samples and phenomena may eschew our understanding of complex systems thinking.

### **Symposium Overview**

The learning sciences community has long suggested that knowledge arises from engagement with cultural practices both within and outside of school settings (Bang, Medin, & Atran, 2007; Nasir et al., 2006). However, most studies on complex systems, focus on how students think about scientific concepts learned in formal environments (Duarte Olson, Forthcoming), with very few papers specifically targeting knowledge of complex systems acquired in informal contexts (Bang et al., 2007; Duarte Olson, Submitted; Olson, 2013). The body of research on complex systems thinking is valuable and informative, however work on how individuals construct complex knowledge in everyday or out-of-school contexts is necessary for the design of more equitable learning environments. Although the knowledge gained from community participation is often analogous to that taught in schools, it is sometimes undervalued (Nasir et al., 2006). Despite the lack of research on everyday knowledge of complex systems, this knowledge is necessary because informal learning practices developed within family and community systems are conducive to systematic and reliable scientific knowledge and important for the development of skills for science (National Research Council, 2009). Moreover identifying this knowledge as scientific could create new paths for diverse communities to embrace STEM careers.

This session is aimed at demonstrating how community practices are an asset and a locus of complex knowledge development. We take on the challenge of discussing how complex systems knowledge can be developed in informal settings with four different studies taking place in diverse community settings. Although the studies approach distinct complex systems, all of them have the same overarching theme: How complex systems can be learned through engagement with a practice. These practices include engagement with the Carnival parade in Rio de Janeiro Brazil, biking in groups, play between children and parent dyads, and teaching climate change. Each of the studies also utilized a wide range of methodologies, ranging from agent based modeling to ethnographic methods, to examine how different practices across 4 different communities afford the construction of complex systems knowledge.

Taken together, the five papers illustrate a wealth of knowledge and a variety of practices co-created within the diverse communities represented. In the first session, we will discuss how expert samba practitioners understand auto-regulation through their understandings of the relationship between samba school and the audience. We focus on how experience with the samba parade shapes more complex understandings of auto-regulation. The second session explores how a community of triathletes used agent-based models to understand the complex phenomena of drafting to increase comprehension and performance. The third session illustrates how Native American children and parents reason about ecological relations that appear in spontaneous play. Finally, the fourth session discusses how a professional development course on climate change can have a profound impact on teachers' understanding of this complex phenomenon. With this, we hope to create a venue to discuss (1) how informal contexts foster the development of complex systems thinking, (2) issues of cognitive diversity in thinking about complex systems, (3) how to use this knowledge to inform design in the Learning Sciences.

## Becoming Samba: Understandings of the Process of Auto-Regulation through the Relationship between Audience and School

Izabel Duarte Olson and Ananda Marin

*Escolas de samba* (or samba schools) are community-based organizations in Brazil. These schools spend an entire year preparing for the samba parade, which occurs yearly during the carnival. They start the year by choosing a theme and creating a *samba enredo* (a theme song). The theme song is usually practiced all year along with any choreographies needed to perform it. The climax is the samba parade, which happens yearly during the Carnival. During this event, schools are judged and ranked with an overall winner. Eighty percent of the school's success is judged by its "harmony" or the way that the members are in synergy with the rhythm, the theme song, themselves, and the audience. Although Rio de Janeiro is a very segregated city, samba schools are a democratic space bringing together working-class and middle-class communities, diverse races and creeds.



Figure 1. The Samba Parade in Brazil

Even though the carnival is purposeful and planned, it is a great site for studying complex systems thinking in the wild as the symbiotic relationship interconnecting audience, school, and each individual member, is what makes a school an overall winner. Moreover, the samba parade is a cultural phenomenon where an enormous amount of complex coordination happens among dancers and mediating structures found in the parade (Hutchins, 1995). Mediating structures are external tools that help one navigate an activity. In the samba parade these structures include the floats, the audience, the section directors, and the beat coming from the instrumental section. Initial fieldwork suggests that there is an unending concern to preserve the emerging unity of the school through coordination among its participants. This coordination among participants allows information to be propagated through these mediating structures with the goal of creating a symbiotic unity in the school, which they call harmony. The result is described as a live organism.

Understanding this live organism requires a decentralized understanding of these coordination processes. With that, the carnival parade could be considered one of the largest participatory simulations in the world. This symposium presentation will explore expert practitioners understandings of the auto-regulation process that results from the schools relationship with the audience. More specifically, we will explore the role of their practice in constructing those understandings. During the parade, the audience functions as a means of feedback. The way the public reacts informs the component of the school's performance, allowing the components of the school (e.g. each individual floor component, section directors) to adjust their actions. During fieldwork, the way the audience reacted greatly shaped what happened on the parade floor. For example, if the audience was animated, the components fed into the audience's reactions and grew. In instances where the audience was cold, the components sensed that and became equally cold.

In previous research, the first author investigated working-class and middle-class individuals understandings of socio-economic mobility. Mobility practices were found to distinctly shape people's understandings of complex phenomena (Duarte Olson, Submitted) as navigating different contexts correlated with more evidence of complex systems thinking. We believe practice also shapes expert Samba practitioners understandings of the samba parade in Rio de Janeiro. Our hypothesis is that our informant's roles and years of practice will be correlated with their understandings of the relationship between audience and school.

### Methods: Population

In-depth interviews were conducted with 52 individuals who had a high degree of involvement with one of Rio's *samba* schools. A high degree of involvement was established by how many years they have been participating in the carnival. At least five consecutive years of participation in the parade were necessary to establish a high degree of involvement with the school. Twenty-three participants were women, while twenty-nine were men. The mean age of participants was 46 years old with an average 25 years of experience in the samba world. As perspective-taking is important for complex systems thinking (Duarte Olson, Submitted) participants had purposefully different roles to see if one's role affects their understanding of the parade.

## **Sampling**

The sampling was purposive. Initial contact was established with several section directors from samba schools, including Salgueiro, Unidos da Vila Isabel and Beija Flor. Based on these initial contacts, potential participants were found through word of mouth and a snowball sampling technique. Participants were not paid for their interviews.

## **Materials and Procedure**

Participants were initially contacted through a referral. Then, if the person agreed, they were later interviewed in their homes, the school, or another location of their preference. The interview instrument consisted of fourteen open-ended questions that examined how individuals reasoned about the relationship between harmony and evolution, audience and school, and the overall interconnectedness of the school. The present research will examine responses to the fourth question in this interview: “Does the audience have a role in the parade? If so, why do you think that?”.

## **Coding**

The interviews were transcribed in Portuguese and later translated to English. The goal of the analysis was to understand how experience (indexed by years) and the participant’s role shape complex knowledge of a practice. To accomplish this goal, the responses were divided into clauses and a code was assigned to each one. As there were differences in the length of the responses, the raw data was normalized by dividing the code clause count by the total number of clauses in each response. Five codes attended to the relationships each participant noted (e.g. Influences from public to school: If the public embraces the school, the school grows or Influence from one component to school: “But that singer sang so well he exhilarated the school”). One code attended to participants’ use of emergent concepts. For example, “We become samba” notes the emergence of a characteristic that goes beyond the school

## **Results**

Understanding the idea of emergence in Samba seems to be correlated with the amount of experience participants have (indexed by years of practice), but not with their actual roles. We ran a 2-way ANOVA with years of practice and role as an independent variable, and the emergence code as a dependent variable. We got a main effect for years of practice ( $F(1, 25) = 2.916, p = .1$ ). This is evident in the way this 63 year-old woman, who has been in the samba world for 50 years, talks about the relationship between the school and the audience: “The audience moves the school, the school moves the audience, together we become samba.” She sees samba as an emergent property of the synergy between school and audience. These two are linked together in such a way that there is no samba if one of the pieces is taken away.

When speaking about this relationship, participants often noted how each component of the parade affects one another. Participants with more experience, quantified by years of practice, were also more likely to mention more types of influences. A 2-way ANOVA found a main effect for years of practice ( $F(1, 25) = 5.43, p = .03$ ), but not role. The more years of experience a component had, the more types of influence the person mentioned. Take Alan’s response, who is 33 and the leader of the instrumental section at a major school of samba in Rio. Alan has been in the Samba world since age 1: “If the public is with you, they sing, if the samba is good, if the school is in a good moment, if the public embraces the school, it is easier. The judges think: Well, I can’t go against this school, because the majority is with them”. Alan, who is an experienced samba practitioner, talks about 4 different relationships when explaining the role of the audience. Most often participants with less experience noted one or two relationships. For example, Ary, a 58-year-old who has participated in the parade for 8 years only notes a one-way relationship between audience and school: “Their role is of motivation [...].”

The role of participants was not correlated with their understanding of their practice. Maybe because during rehearsals there is not much distinction between roles, unless you are part of one of the more specialized sections (e.g. instrumental section). Therefore, the interaction that is consistent six months out of the year is more crucial in shaping your knowledge of samba than what happens in 30 minutes during the parade floor. However, experience was predictive of people’s understandings of emergence and the number of relationships people mentioned in their response. Practitioners that had more experience (indexed by the number of years in the practice) were more likely to mention emergence and more relationships. This paper shows the importance of practice in learning complex systems thinking knowledge and invites the learning sciences community to look for more that are the locus of complex systems knowledge development.

# **Collaborating while Competing: Conceptual and Motor Learning While Inventing Drafting Tactics with Agent-Based Models of the Aerodynamics of Bicycle Drafting**

Alon Hirsh and Sharona T. Levy

Can a constructionist complex systems approach support better understanding and performance in sports? In this paper, we describe research into young triathletes' invention and execution of new drafting tactics using computer models based on a complex systems approach. The tension between cooperation and competition invoked while biking in groups within a triathlon competition is problematized as a substrate for learning regarding the aerodynamics of collective motion through air. The present study presents a curious finding that runs contrary to well-established motor learning theory (Schmidt & Wrisberg, 2008) that claims that conceptual learning precedes and promotes motor learning: how learning through constructing collaborative tactics for overcoming air resistance via a complex systems perspective enhanced athletes' biking performance but not their conceptual understanding of the very same topic.

The study involves a model-based triathlon training program, Biking with Particles, concerning aerodynamics of biking in groups (drafting). A conceptual framework highlights several forms of access to understanding the complex system (micro, macro, mathematical, experiential) and bidirectional transitions among these forms, anchored at the common and experienced level, the macro-level (Levy & Wilensky, 2009). The goal was to explore whether using agent based models of bikers and air particles to learn about drafting could be used to enhance athletes' understanding and performance. Motor learning and conceptual learning of the aerodynamics of drafting were compared.

## **Triathlon and Drafting**

The triathlon is a multisport event, which was established some 30 years ago. The three disciplines in the event are swimming, cycling and running. A triathlete performs the three sports in the specified sequence and strategizes effort and speed to obtain maximum effect in minimum time. The distance in each sport is determined by age. In the adult category the distance for swimming is 1500m, cycling 40km and 10km for running. In the current study, our participants were youth and performed 50% of the adult requirements in competitions. The term drafting is mostly used in the field of physiology and biomechanics of sports to name the movement of closely packed individuals aimed at aerodynamic protection (Hausswirth & Brisswalter, 2008). A peloton is a large group of cyclists that are riding together to create a network that spreads energy resources among the cyclists. A peloton is usually created spontaneously. One of the main reasons for losing energy during cycling is due to friction with the air. The aim of drafting is to reduce this friction. Little research has been conducted into the impact of drafting in triathlon on physiological factors.

## **Cooperation/Competition**

Drafting is used to gain energy advantages in moving through the air (Hausswirth & Brisswalter, 2008). The phenomenon of drafting offers unique insights into the delicate balance between competition and cooperation among collectives. On one hand, drafting offers up to 40% savings on energy expenditure, rising with the biker's speed (McCole et al., 1990). On the other hand, the group speed may slow a biker down too much; in which case, a smaller group may "break-away" usually around a bend in the road. Thus the persistent question for a given cyclist is "stay or break away". Furthermore, the answer can change at any given moment. In a triathlon (sequenced as swimming, biking then, running), biking at a less than maximal rate and minimum energy expenditure is particularly advantageous in saving energy for the last leg of the competition.

## **Conceptual/Motor Learning**

This study examines both conceptual learning and changes in performance. Performance is viewed through the motor program construct (Schmidt & Wrisberg, 2008). The motor program is an abstract representation of movement, used to describe cognitive processes in movement planning that include both pre-programmed movements and responses to environmental stimuli. This construct is central in sports research. It is fundamental to the current study as we expected that the resulting motor program would include greater flexibility with respect to environmental conditions, sensations with respect to air pressure, and flow. This flexibility is related to both sensing of input (sensorial input related to the tactile and haptic senses) and to related movement, such as shifting position to better locations within a configuration. Motor learning is described as having three stages: (1) cognitive-verbal; (2) motor; (3) autonomous. Within this study, we have focused on the first stage, cognitive-verbal learning that may take place through exploring and discussing computer models. In the cognitive-verbal phase, the learners do not yet know the topic and skill they will learn. During this time they talk to themselves, ask questions about confusing issues and ask self-monitoring questions. In Biking with Particles, we have provided a learning environment that encourages such talk and questioning, by providing several opportunities to self-explain, explain to others, listen to and assess explanations (Chi & VanLehn, 1991). Perceptual learning

and conceptual learning are also conceptualized as part of motor learning. In the early stages of motor skill learning, the athlete needs to experience the skill at the conceptual and perceptual level (Schmidt & Wrisberg, 2008).

### **Expert/Novice**

It has been claimed that in most fields of sports, athletes need to process information very quickly in an environment where time is a crucial factor (Williams et al., 2010). Therefore, athletes need to adapt themselves to unique constraints of the task by learning knowledge structures and cognitive processes that support their prediction of what will happen and deciding on the appropriate choice of action (Williams & Ford, 2008). The above researchers claim that experts circumvent the limitations of short-term memory by learning skills that facilitate quick processing of information into long term memory and selective access to this information, as needed. After extended practice, experts tag information in such a way that enables anticipation of when it will be needed in the future. In a meta-analysis of the relationship between expertise and perceptual-cognitive skills, several distinctions were found among novices and experts in various domains in sport (Mann et al. 2007). Notably experts were better at identifying perceptual cues.

Training was conducted separately with two groups, both 14-17 years old youth: an elite junior triathletes team (experts; 4 male, 3 female) and a local team (hobbyists; 6 male, 3 female). The study lasted three days and included lectures, discussions, guided exploration of agent-based models of concerted motion through air particles (Levy, Hirsh, Bacalo & Kakoon, 2011), inventing new tactics, and biking in practice. Data included questionnaires, interviews, videotapes, and performance measures of heart-rate and biking duration.

The athletes' invented designs were innovative and diverse, expressing well-known (diagonal placements, one-behind-the-other units, aerodynamic group contour, rotation in motion) and new features (wrap the weak, strong in front) in the sport. Local features (e.g. diagonal placements) were more dominant than global features (e.g. aerodynamic group contour). While displaying some well-known principles, the tactics themselves were original, new to the sport. The athletes' designs introduce new tactics of drafting that incorporate an idea of uneven load distribution. In optimizing a solution that balances across the tension of cooperation and competition, the weaker cyclists' performance that is detrimental to the group was alleviated by creating vacuum bubbles. These bubbles were used to encapsulate the weaker riders, making it easier for them to ride, without impacting the group performance. A heavier load was placed on the strongest riders, while negotiating the energetics of this arrangement to make sure the strong bikers still obtained energetic benefits.

Their performance in bicycle drafting increased dramatically, with a gain of 20%, at both individual and group levels. The experts mainly reduced their times. Hobbyists mainly reduced their effort. The gain was measured with respect to the currently known best drafting tactic, the Belgian Tourniquet – named, BT (Hausswirth et al. 2001) that involves rotating placement and leadership within an ellipse of bikers. Computation of this efficiency was based upon the ratio of output to input; the invested effort (input measured as heart-rate from resting baseline) and the performance outcome (output in terms of speed or time) thus introducing a concise new efficiency measure into the field of sports. For each group, the tactic with the best efficiency was compared with the BT. The experts improved in efficiency by 19%. The hobbyists improved in efficiency by 20%. For each athlete, the best efficiency among all invented tactics was recorded. The mean efficiency was .99 (.18), with higher mean efficiency for the experts [1.13 (.11)] than for the hobbyists [.86 (.13)], with an unpaired  $t(11) = 4.01^{**}$ .

Some conceptual change was evidenced for the micro-level complex systems components (particulate nature of air, paired  $t = 2.43^*$ ), and micro/macro relations (paired  $t = 3.74^{**}$ ) but not regarding how these emerge into drafting patterns. Generally, the athletes' explanations of drafting from the more basic definitions and until more complex problem solving did not change.

We had found the triathletes' designs to be innovative, proliferate, and diverse. Their inventiveness goes beyond the single and double line, or the BT described for triathlon competitions. Older central triathlon coaching texts do not mention drafting at all. The newest coaching text to date (US Triathlon 2012) describes only the rudimentary tactic of a single line. As drafting is a relatively new and still-contested feature in triathlon competitions, it seems that there could be much room for growth. The junior triathletes introduced several new tactics into the field of competitive bicycle riding in triathlons, a significant achievement.

We have seen a radical change in performance, not usually evidenced in the domain of competitive sports. The triathletes improved their efficiency (speed with respect to effort) by 20%, both as a group and as individuals. Improved performance is related to greater speed, expending less effort, and staying within the aerobic range. A methodological contribution of the current study is developing a metric for the main factors as a single efficiency measure. This measure supports comparison between tactics.

One may wonder as to the small rise in conceptual understanding when such a large increase in performance was under way. While the athletes learned the basic physics of air particles' motion and could use the ideas of air density to understand effort, they did not improve their understanding of drafting. Motor learning has been described as going through three stages: (1) cognitive-verbal; (2) motor; (3) autonomous (Schmidt and

Lee 2011). It seems that in this study, the cognitive-verbal stage was cut short, and partly “skipped over” so that most of the learning happens at the motor stage. This finding begs the question of whether the first stage is a necessary pre-requisite for the second stage. It suggests that with motor skills, one does not have to verbalize what one understands in order to perform it. Processing in the motor learning stage involves making performance more adaptive and efficient. It would seem that the visual and spatial information provided by the models and completed by the athletes’ imagination and mental simulation could be enough to create a solid basis for improved action. The highly visual and dynamic quality of the computer models leads to incorporating the ideas they offer into perceptual-motor schemes without going through the channel of verbal explanation.

## **Emergent Complex Systems Reasoning: Cross-Cultural Differences in Reasoning about Eating Relationships between Kinds**

Megan Bang, Priya Pugh, and Douglas Medin

Although some scholars have argued that biology is a core conceptual domain that is organized in terms of universal principles of categorization (e.g. Berlin, 1992) and a domain which is associated with a universal developmental unfolding (Carey, 1985), there is accumulating evidence of broad cultural differences in knowledge organization and suggestive evidence on variable developmental trajectories (e.g. Medin and Atran, 2004; Hermann, et al, 2010). In our work we have been investigating the cognitive consequences of relational epistemologies on knowledge, knowledge organization, attentional foci, and sense-making about the natural world more specifically (Medin and Bang, *in press*). We have found significant cultural differences in conceptions of human/nature relations that are manifest in explicit knowledge and values and implicit in practices and conceptual organization (Bang et al, 2007, Medin et al, 2006). Further, we have found that rural Native-American children employ ecological reasoning developmentally earlier than rural, European-American children and that rural children in general use ecological reasoning earlier than urban (Non-Native) children (Ross, et al, 2003). In the current work we are hypothesizing that these differences in ecological organization of knowledge may develop from differences in psychological closeness and whether a systems perspective, focusing on relationships, is adopted. One way to study this is through the examination of young children and their caregivers communication and engagement in sense-making about the natural world. This study asked 61 parent-child dyads across two cultural communities to play with a 3-d diorama forest. The content and focus on the spontaneous talk during the task comprises the data for this study. To develop this work we briefly explain, what relational construals might mean and the specific domain of relational construals taken up in this study. Before we present our current work we also provide a brief overview of psychological distance and perspective taking. We develop predictions for the content and structure of the talk we anticipated given this theoretical background, discuss our methods, and present our findings.

### **Relational Construals, Psychological Closeness/Distance, Perspective Taking**

There are various strands of work that contribute to our understanding of relational construals and this term is intended to incorporate this broader landscape. In part this terminology is drawn from ecological knowledge organization and reasoning patterns (Atran & Medin, 2008, Medin & Atran, 1999). Other work has explored associative relational patterns that children perceive in the world (i.e. Keil, 2003). Still other work has suggested that Indigenous thought is foundationally based on constructions and meanings of relationships (Cajete, 1999). For the present purposes we focus on the relational construals in the context of eating relations between kinds. Trope and Liberman (2003) proposed that psychological distance affects cognitive processing at least around physical distance, temporal distance and social distance wherein psychological distance is associated with attention to abstract features and the whys rather than hows of phenomena among other things. Psychologically close events are associated with (a) greater attention to context and mitigating factors and (b) a greater likelihood of interpreting social behavioral situationally rather than dispositionally. CLT is also relevant to perspective taking. For example, being in a position of power (by hypothesis, being more psychologically distant) may be associated with a failure to take the perspective of other actors or to take situational factors into account in judging the behaviors of others (Galinsky, et al., 2006). CLT predicts that psychological closeness facilitates perspective taking and there evidence suggesting that cultures differ in the ways in which they deploy psychological distance and perceptive taking (e.g. Masuda et al., 2008). There also are correlated cultural differences in the likelihood of spontaneously taking another person’s point of view (Wu & Keysar, 2007; Leung & Cohen, 2007). In our work we have found that psychological distance impacts the features and content attended to in the natural world (e.g. Medin & Bang, *in press*).

### **Predictions**

Given the cross-cultural differences around ecological knowledge organization, and the theoretical implications of psychological distance, and perspective taking, we predicted seeing the following differences between Native and non-Native dyads.

1. Native dyads would have more kinds (living things) involved in eating relations than non-Native dyads.
2. Native dyads would have a wider variety of forms of eating relations (e.g. food webs, food chains, etc.)
3. Non-Native dyads would demonstrate more psychological distance in the use of generic forms of kinds (e.g. bears), while Native dyads would use more specific forms (e.g. this bear).
4. Native dyads would demonstrate more spontaneous perspective taking measured by different ways of narrating eating relations and attention to internal states of the focal kinds.

## **Participants**

This study engaged 40 Native American parent-child dyads and 21 European-American parent-child dyads. Native children and parents were recruited from the Menominee reservation and the Chicago Urban Indian community and from the town of Evanston, IL USA.

## **Materials**

Parents and children were given a 3-d diorama about 1.5 feet long by 1 foot wide of a forest ecosystem that included stationary parts (trees, rocks, a pond, a log) and moveable parts (trees and animals including a: cow, gorilla, zebra, deer, bear, turtle, and eagle).

## **Procedures**

The researcher set up a video camera and the materials in front of the parent-child dyads on a table. The researcher invited them to play with the diorama and indicated she would be back in 20 minutes, leaving the camera running. The video tapes were transcribed. Analysis was conducted on both the transcripts and the video data for both verbal and non-verbal expression of eating relations. However the findings in this paper are only derived from the forms of eating relationships expressed in the talk.

## **Coding & Analysis**

The data was coded along four dimensions including: kinds focused on; forms of relations between kinds in eating relationships, use of generics versus specifics; and presence of internal state ascription. The kinds focused on dimension and forms of relations code had subcodes. *Kinds focused on* referred to the type of living and non-living things talked about in eating relations. These codes included: animals, mammals, reptiles, insects, fish, birds, plants, and water. *Forms of eating relations* including the following five codes: properties of kinds (e.g. bears eat fish); food chains (e.g. bears eat fish and fish eat worms); food webs (e.g. bears eat fish and eagles eat fish); and feeding relations (e.g. mother eagles feed their babies). Each eating relationship was coded for whether it was in the form of generics (e.g. bears) or specifics (e.g. this bear). Finally, for each eating relationship talked about, the presence of interpretation of the internal state was coded for.

## **Results**

Preliminary results (we will have a second coder to ensure reliability) reveal cross cultural differences across all dimensions. Each are reported.

1. *Kinds focused on.* A chi-square test of independence was used examine the relationship between cultural community and kinds focused on. The Native dyads were significantly more likely than the European American dyads to include eating relationships that included insects ( $\chi^2 (1)=23.6$ ,  $p<.01$ ), fish ( $\chi^2 (1)=4.98$ ,  $p<.03$ ), birds ( $\chi^2 (1)=6.22$ ,  $p<.03$ ), and plants ( $\chi^2 (1)=10.28$ ,  $p<.01$ ). There was no difference between cultural communities inclusion of animals, mammals, reptiles, and water.
2. *Forms of eating relations.* A chi-square test of independence was used examine the relationship between cultural community and forms of eating relations. The Native dyads were significantly more likely than the European American dyads to reflect forms of eating relationships in food chains ( $\chi^2 (1)=7.572$ ,  $p<.01$ ), feeding relations ( $\chi^2 (1)=3.88$ ,  $p<.05$ , and to have multiple forms intersecting ( $\chi^2 (1)=6.25$ ,  $p<.03$ ). There was no difference between cultural communities use of food webs and properties of kinds.
3. *Psychological distance via generics and specifics.* A chi-square test of independence was used examine the relationship between cultural community and use of generics and specifics. The Native dyads were significantly more likely than the European American dyads to use specifics ( $\chi^2 (1)=3.86$ ,  $p<.05$ ). There was no difference between cultural communities use of generics.
4. *Perspective taking via eating directions and internal states.* A chi-square test of independence was used examine the relationship between cultural community and perspective taking. The Native dyads were significantly more likely than the European American dyads to reasons from prey to predators ( $\chi^2 (1)=5.7$ ,  $p<.03$ ). They Native dyads were also far more likely to attend to the internal states of the focal kinds ( $\chi^2 (1)=11.6$ ,  $p<.0001$ ). There was no cross-cultural difference in reasoning from predators to prey.

## **Discussion**

The significant difference in children and parent talk found in these studies suggests that Native children and parents are far more likely to engage in thinking about eating relations with a wider range of kinds, with a variety of forms of relationships between those kinds. These various forms may have implications for how more complex reasoning patterns emerge because they are routinely engaging in a variety of cognitive patterns as compared to non-Native dyads. Further these results demonstrate that the Native dyads are more likely to engage in psychological close reasoning and perspective taking. We suggest that reasoning from predators to prey is a form of perspective taking in explore eating relationships rather than always reasoning about eating relationship from predators to prey. Further attending to the internal states of the focal kinds suggest that Native dyads are thinking about the context of the eating relations event from multiple perspectives. This spontaneous difference in parent-child talk would have significant long-term impacts on children's cognitive development.

## **Nat's Maps: A Case Study in Climate Change Cognition**

Megan McGinnity

Climate change is an example of a complex nested system that is causing profound and rapid changes in every natural system that we depend upon (IPCC, 2007). As a result the Next Generation Science Standards (NGSS Lead States, 2013) call for teaching global climate change. At the same time, an ongoing challenge in education is to develop an accurate understanding of (and to teach) complex systems (Plate, 2010). Research indicates that students and teachers don't understand complex systems very well and pedagogical norms have not yet been established. (NRC, 2012, Plate, 2010)

Simplistic understandings lead to simplistic, linear and inadequate solutions (Venville, Rennie, & Wallace, 2012) and linear causal patterns do not reflect the phenomena of causality in systems (Lagnado et al., 2007; White, 1992). When aspects of the Earth's climate system are taught according to a high school curriculum, they are usually parsed into separate, specialized disciplines, such as biology or chemistry. This approach can be problematic (NRC, 2012; Venville, Rennie, & Wallace, 2012) in that does not portray these disciplines as a series of steps in a greater whole and can go in the opposite direction by mis-rendering a complex problem as simple and misleading students towards a simple solution.

Concept maps have been used as a tool to explore students' understanding of complex systems and climate change (Rye & Rubba, 2002), but they do not address the issue of causality. Lagnado et al (2007) found that most people represent causal knowledge qualitatively, in a series of linked events, while White (1992) described causal hierarchies in which participants described natural processes as one-directional, with humans being at the top of the chain. This study sought to investigate how environmental educators understand and reason about climate change and to determine what the participants learned in this professional development. A case study was used to investigate the conceptual structures and dynamics of one educator's understanding and how they changed over the course of the professional development period. The participants in this study were environmental educators undergoing a professional development in climate change. "Nat" was an experienced environmental educator who characterized himself as 'not comfortable with science'.

This study drew upon traditional methods in cognitive science where participants draw their own causal maps to make their reasoning visible (Kearney and Kaplan, 1997). Plate (2010) proposed a program called Cognitive Mapping Assessment of Systems Thinking (CMAST) that focuses on the creation of web-like causal structures. These causal maps represent the flow of cause and effect, communicating an individual's metacognitive knowledge and can make their conceptual inferences and connections more explicit (Plate, 2010). The card task used in this study was derived from Plate's CMAST methods and adapted to allow for relationships where participants suspected causality between two factors but were unable to specify the nature.

The participants were given a set of cards that contained concepts affiliated with climate change. They selected the term needed to describe climate change to a person unfamiliar with the topic. Once the cards were selected, the participants divided them into groups and named each grouping. All the selected cards were then stacked together and laid out one at a time on a large sheet of paper, drawing the relationship, if any, between the two cards. After the relationship between all the cards on the sheet were established, the next card was added and the process repeated. By the end of the exercise, a web of causal influence-relationships between all of the items had been mapped out. Tasks were administered before and after the professional development period, yielding pre- and post- maps.

Two types of analysis were employed in looking at the maps: structural & dynamic. Structural analysis focused on the structures within the map while dynamic analysis was concerned with Nat's reasoning in drawing the relationships between the concepts. Conceptual nodes (cards / terms) & conceptual links (arrows). Plate, (2010) used 'link density' to determine how many concepts were being incorporated into a map. As a score, it is the ratio of links to nodes in a given system map. However, one shortcoming of link density is that it does not measure the complexity of branching and loops in a map. Branching in the occurrence of more than one arrow to/from a concept and indicates multiple causes and effects in reasoning about a particular concept.

Loops are a return to an earlier concept in a chain of reasoning and represent reciprocal relationships. Map complexity can be better quantified by using a Web-like Causality Index (WCI), a score calculated by adding the percentage of nodes with more than one cause to the percentage of nodes with more than one effect.

Nat's pre-map had a link density of 3.30 with eleven loops and his post-map had a link density of 2.09 with two loops. The drop in link density scores and loops could be seen as a simpler causal post-map, but this may also be a sign of increasing expertise as Nat became able to discern and select the most salient concepts (Bransford, 2000). This is further supported by the pre- and post- WCI scores of 0.42 and 0.49 respectively, indicating a greater complexity in his post- map.

The dynamic analysis was used to develop some measure of Nat's ascription of causal impact to a given concept in the map. When Nat grouped and labeled his selected card terms, one group was labeled "Human-caused things/ Things that humans are doing". That group held four terms (deforestation, human consumption, industrialization, and greenhouse effect). These terms, along with the term "fossil fuels" were designated as 'human-determined', meaning that they are directly related to human actions or are implicated heavily in human actions that affect the climate. In looking at the relationships between the concepts, two key questions were determining when were they the sources or recipients of causation and how often they were implicated.

A causal "agency" measure was created to assign a score to all the node terms in the causal map. In this case, the word 'agency' is the amount of influence a noded term has on other nodes. When an arrow originated from a node, that term was considered to have a source arrow. If the node was the terminus of an arrow, that term was considered to have an influencing arrow. Each term was then assigned a Causal Agency Index score, where its source arrow score was subtracted from its influencing arrow score. Overall, human-influenced terms decreased in causal agency while natural terms rose in agency from pre- to post-.

The frequency measure was determined by the number of times the term (node) was connected to a second term. The results are displayed in Figure 2. The human-determined terms on the rose are clustered at the bottom. There is a noticeable pre- to post- shift in the prominence of the human-determined terms while some natural terms and processes gain in frequency. In short, this figure demonstrates an overall decline in the activity of the human-determined terms and an increase in terms associated with natural processes.

In summary, Nat's thinking about climate change & complex systems changed from the pre- to post-measures. Structural analysis suggests increased expertise and greater complexity in his thinking while dynamic analysis indicates a shift away from human-determined terms in both ascription of agency and usage in the maps. The concepts of agency and the role of humans have great implications for our ability to teach complex natural systems and can better inform further study in developing curricula that help us to understand and teach complex natural systems.

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# Learning as Multi-Dimensional Psychological and Cultural Ecological Spaces

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**Abstract:** This symposium addresses challenges of understanding learning as multi-dimensional and embedded within and across multiple levels of contexts. Each paper articulates frameworks for designing and evaluating the impact of interventions in single and multiple settings that explicitly address how issues of identity, relationships, and belief systems within and across non-dominant communities can be leveraged and understood to support robust learning. Paper one presents a multi-dimensional, ecologically focused design framework for supporting literacy as identity building among a cohort of African-American urban adolescents and presents data from a longitudinal study implementing the framework. The second presents the framework for a multi-site ethnographic methodology conceptualizing learning as expansive, focusing on generative repertoires for learning in diasporic and other non-dominant communities. The third presents design principles enacted in a program for African-American adolescent male development addressing issues of identity, perceptions, and relationships as drivers for robust learning and implications for policy and practice.

## Symposium Overview

This symposium addresses the challenges of understanding learning as multi-dimensional and embedded within and across multiple levels of contexts. In contrast to much of our efforts to address learning as essentially a set of cognitive processes within the minds of individuals and even attention to the dynamic interactions among people within settings where people learn, these symposium papers attempt to target the design challenges of a conceptualization of learning that goes beyond these traditional constraints. We will first describe the conceptualization of learning that informs the research presented across papers.

There is an increasingly accepted proposition that learning entails the transformation of cognitive processes for individuals through people's interactions with one another and artifacts over time. However, there is also a strong accumulation of evidence from across disciplines that the processes through which humans actively engage in learning include their perceptions, their emotional states, and their relationships with others. The mechanisms through which these occur are embodied in physiological processes. Perceptions of the self, of tasks, of settings, and others with whom we interact matter for goals and effort. These perceptions include emotional states and impact the nature of relationships that we strive to develop. These perceptions are deeply influenced by the broader ecologies in which we live, such that shared values and practices around kinds of identities (regarding gender, ethnicity, race, class, and abilities) matter. The sources within the various contexts in which we routinely participate (e.g. family, school, peer social networks, neighborhoods, the cultures, institutions and practices within nation states and across diaspora communities) provide a hybrid medium for the construction of these perceptions over time. These multi-dimensional intra-psychological processes (e.g. cognitive, emotional, phenomenological, social) interact with features of learning environments that inevitably entail multiple settings. Moreover, what kinds of learning environments are available to us are highly linked,

especially in the U.S., with class, race, and ethnicity. One of the limitations in education broadly speaking and in the learning sciences has been the dominance of hegemonic belief systems about the affordances of different contexts for learning, compounded by particular constraints imposed largely by economic status (e.g. underfunded schools; "food deserts"; inadequate access to health care; few neighborhood youth organizations, etc.).

And so we argue that attention to the design of robust learning environments requires understanding: (a) the multiple cognitive, social, phenomenological, physiological and emotional processes that are deeply intertwined in acts of learning; (b) the ways that these multiple intra-psychological processes of learning are influenced by participation in current and historical cultural practices; (c) the centrality of relationship building; (d) the repertoires that are both available and developed through people's participation within and across the multiple settings of their lives; and (e) how these repertoires are deeply connected to contemporary and historical cultural ecologies as well as to political and economic ecologies. These complex relationships entailed in learning are also deeply sensitive to time, especially time within and across the life course; and so understanding patterns of development within cultural communities from childhood into adolescence into adulthood matters for what learners must wrestle with and what repertoires are available to them for such wrestling. And finally, we will argue for a discipline specific focus on the tasks or objects of learning. By disciplines we refer not only to forms of academic knowledge typically associated with learning in schools, but equally to forms of disciplined knowledge entailed in a variety of learning tasks outside of school.

We think that a significant center to this multi-dimensional psychological and ecological space we have described has to do with the work of identity building and thus is connected to the conference theme of "Learning and Becoming in Practice." We hope to push this theme by proposing that this intellectual space we have described affords multiple identities, becoming persons who can navigate within and across multiple spaces, and explicit attention to the ways that political and economic positioning can complicate what learners must wrestle with in order to develop multiple identity repertoires and possibilities of becoming.

We are very clear that these grounding propositions are wide ranging and as a consequence difficult to capture in the design of robust learning environments and in thinking about the kinds of data and methods of analyses we will employ to understand what and how people learn in such designed environments. The papers in the symposium offer models for approaching the kind of complex, multi-dimensional and multi-contextual learning we have described. Each paper articulates the rationale for addressing the multiple dimensions identified in the problem space we have described; describes the rationale for how the questions posed attempt to struggle with this complexity; and describes how the data collection and methods of analysis seek to examine complex multi-dimensional relationships in ways that take culture as well as political and economic positioning into account.

## Multidimensional Design Framework for Learning as Identity Work

Carol D. Lee

This paper documents the Cultural Modeling Eco-Cultural, Developmental and Psycho-Social Design Framework that embodies the multi-dimensional and ecological focus of this symposium. The goal of the design research is the transformation of a low-achieving urban high school serving a low-income African-American population to improve literacy outcomes in terms of reading and argumentation in the disciplines. This design stands in contrast to more traditional design research to support academic learning in that it goes beyond attention solely to the cognitive structures underlying the growth of expertise and beyond attention primarily to interactional patterns within classrooms. These more traditional approaches, even within the Learning Sciences, tacitly presume students will be active participants under the features of the designed environment and that who the students are doesn't really matter. Such interventions, especially in the contexts of schools, run up against the challenges of schools as organizations that can substantively unravel the intervention; and the challenges of teachers' opportunities to learn to engage new practices.

This design is multifaceted, focusing on psycho-social as well as cognitive needs of students, on schools as learning organizations that enable learning among adults and students, and on the specific literacy demands of reading in the disciplines. In each focal area, the design requires gathering and building on data that informs what students bring as challenges and repertoires of reasoning and practice that are sometimes complementary and sometimes in tension with the requirements of robust schooling, understanding that these challenges and repertoires are situated inside historical, cultural, social, political and economic ecologies that surround these young people. These foci entail identity work for students, for faculty and staff, and for the school as an organization. For students the intervention supported wrestling with "Who am I?", "Who and what can I become?", and "What is available to me to help me?"

Specifically, the literacy interventions in disciplinary classrooms make discipline specific strategies for critical comprehension explicit through modeling and scaffolding; the modeling and scaffolding draw from the Cultural Modeling framework to build upon tacit understandings of strategies based on students' everyday

repertoires; the content and thematic foci in instruction invite wrestling with explicit social, economic, cultural and political issues that emerge from the ecologies of youths' communities through the examination of texts and production of written and oral arguments. Socio-emotional supports are designed through teachers and staff serving as individual personal advisors for students, enrichment clubs aimed at expanding the horizon of possibilities available to youth in the school, specialized support services (anger management groups, conflict resolution groups, trauma groups, teen parenting groups) as well as structures for student leadership (grade level student councils, leadership roles in clubs, participation in the process of hiring new teachers, restorative justice group). Attention to organizational learning occurs through faculty leadership in all aspects of the school, including the collection and analysis of data on all aspects of the intervention; and through structures such as the Instructional Leadership Team, faculty committees, weekly data driven full faculty/staff meetings; and through professional development ranging from studying adolescent development to the demands of reading in the disciplines. This intervention design is comprehensive in its efforts to address the multidimensionality of learning processes, the complexities of the broader ecologies of students' lives, the specificity of disciplinary learning demands, and the structures of organizations as learning communities in which these activities are supported. Specifically this program of design research seeks to examine person-context-process relationships.

This complex framework requires a broad array of data collection. In order to document what in the contexts of the communities from which these youth came posed challenge and opportunity we collected epidemiological data on neighborhood density, housing, poverty distributions, crime rates, presence of food deserts, and availability of community youth organizations and health care. This allowed us to create cases reflecting the broader ecologies through which youth had to navigate and our design had to address. In order to document intra-psychological orientations with regard to identity and perceptions of threat, of ability and the school context, we administered an array of validated survey measures. To document proximal processes of classroom instruction, we collected video data and analyzed for participation structures that supported close reading and argumentation. To further ground these observations, we collected samples of student work that reflected the architecture of the literacy intervention. To document proximal learning outcomes, we administered discipline specific pre-post assessments evaluating close reading and argumentation. To document distal transfer learning outcomes, we used data from PSAE scores. This is the 2<sup>nd</sup> year of a 3 year longitudinal study where we examine not only nested relationships among these categories of variables (identity and phenomenological; process data; and learning outcomes) within a given year, but across years. We have a longitudinal focus because of our developmental lens proposes that there will be differences between early and late adolescence.

## **Findings**

Findings show, despite data showing that most students experienced significant traumas outside of school, adaptive coping and positive racial identity as well as comfort with others, a belief that ability is malleable and reading with a social justice and personal meaning making orientation were positively correlated with gains in reading.

## **Significance**

Efforts to address the challenges of low-performing urban high schools typically focus on organizational accountability via test scores through efforts aimed solely at curriculum and/or professional development interventions. This study, grounded in understanding learning as entailed in identity processes that are sensitive to life course development, offers a holistic model of school transformation that integrates a focus on deep disciplinary knowledge with regard to content area literacies and attention to the social and emotional demands of rigorous learning, as these are complicated by positioning in non-dominant communities plagued with poverty. The significance is both conceptual as well as methodological, as exemplified in the multi-dimensional design of the intervention and the layers of data collection and analyses employed.

## **Studying Movement, Hybridity, and Change: Towards a Multi-Sited Sensibility for Research on Learning across Contexts and Borders**

Shirin Vossoughi and Kris D. Gutiérrez

In this presentation, we bring together cultural-historical approaches to human development with interpretive and multi-sited ethnography as a means of working the intersections between expansive theories of culture and learning and methods that place human activity at the center of analysis (Cole, 1996; Erickson, 1986). We argue that this discussion will help us develop ethnographic tools that attend to the ways young people learn within and across multiple contexts, and glean principles that help constitute a "multi-sited sensibility" (Marcus, 1995) appropriate for taking a more expansive approach to learning, and a more adequately complex stance towards young people from non-dominant and diasporic backgrounds (Vossoughi & Gutiérrez, in press). In line with our previous work on social design experiments — design based research oriented towards transformative and

consequential learning — we offer resources for the design, practice, and study of education *as it could be* (Gutiérrez & Vossoughi, 2010).

We are interested in understanding, designing, and sustaining learning environments that account for the institutional, political, and social demands and contradictions youth negotiate as they move in and across the ecologies that constitute everyday life (Ito, et. Al., 2013; Nasir, et. Al., 2006). Following Gutiérrez (2008), we use the metaphor “learning as movement” to call attention to the ways in which youth develop repertoires of practice, and to push on extant theoretical understandings in which the cultural nature of learning is underspecified or misunderstood. We offer an alternative to methodological approaches that do not account sufficiently for current sociopolitical and demographic realities, or attend to the literal and symbolic borderlands and hybrid spaces that give refuge to and engender ingenuity for diasporic and non-dominant communities. In contrast, multi-sited research is centrally concerned with displacement, hybridity, and multiply constituted subjectivities. This approach is useful for unsettling normative assumptions about culture and learning and retooling our interpretive lenses for the intellectual work involved in navigating modern borders in all their myriad macro- and micro-political forms. From a multi-sited perspective, such interpretation involves attending to the ways young people forge new connections and forms of resistance, and participate in the creation of hybrid environments and tools.

A “multi-sited sensibility” for studying learning across contexts may therefore inquire into the ways people, ideas, tools, artifacts and questions, move and become reconstituted across the boundaries of school, home, and community spaces *and* across the multiple contexts and environments that constitute a single setting. As equity-oriented researchers, we emphasize the fact that such movement is always mediated by questions of power and politics. In this vein, we ask: Whose linguistic, cultural, and intellectual resources are free to move across settings or hybridize, and whose are prohibited, devalued, and marginalized? How do teachers and students enact, disrupt and reimagine these boundaries in everyday practice? How might the borderlands create particularly rich opportunities for students to syncretize and ply their learning? We consider how developments in multi-sited ethnography (Falzon, 2009; Marcus, 1998; 2009) offer tools for grappling with these questions, and for challenging the imposition of normative cultural categories on the learning experiences of young people from migrant, immigrant and diasporic backgrounds.

Our broader interest lies in developing methodological and theoretical resources for the creative expansion of equity-oriented educational research and practice. To this end, we articulate the contours of a multi-sited sensibility as an emergent tool, one that we hope offers new ways of seeing, listening, understanding and working to identify spaces for potential and possibility across the settings young people experience and traverse in their everyday lives. We argue throughout that a “multi-sited sensibility” draws on the analytic power of ethnographic approaches to study and advance conceptions of *learning as movement* in ways that call attention to cultural repertoires that are necessarily co-constituted and leveraged across places, spaces, and time scales. We are drawn to the notion of a methodological “sensibility” as we believe it connotes and invites us to develop a *disposition* towards equity-oriented and ecologically valid research that can be generative for both single and multi-sited ethnographic studies.

## **Creating Productive Ecologies of Learning for African American Students: Successes and Challenges in Oakland**

Na'ilah Suad Nasir and Maxine McKinney de Royston

Learning scientists have attended to the ways that creating optimal learning environments requires attending not only to the cognitive dimensions of learning, but also to the identity dimensions, the interpersonal dimensions, and the ways that learning arrangements are cultural and racialized spaces (Nasir, 2012, Polman & Miller, 2010). While scholarship in the learning sciences has begun to examine these psychosocial dimensions of learning, contexts of learning, especially those related to school, also involve policy and district contexts which are consequential to the way learning environments unfold, and the ways they engage students from marginalized groups.

This presentation focuses on a district-wide initiative, the African American Male Achievement Initiative (AAMAI) in the Oakland Unified School District, and describes the learning opportunities created by the initiative in two key ways: 1) a focus on whole school reform to support the success of African American students, and 2) all-Black, all-male “manhood development” courses which were offered to 9<sup>th</sup>-10<sup>th</sup> grade students in several district high school and middle schools. Our analysis highlights the multiple levels of policy and practice, from the ideologies and policy decisions at the district level, to school level implementation, to the nature of experiences (experiences of learning, of identity-building, and of engagement) that get enacted at the school and classroom levels. We draw on data from a multi-year study of the AAMAI, including a 3-year study of the manhood development classes, and emerging findings from nine whole-school case studies (including observation at the school and classroom levels, and interviews with administrators, teachers, parents, and

students) of middle and high schools with varying levels of success in increasing learning opportunities for African American students. Findings show that learning opportunities for African American students in Oakland were influenced by factors at each of multiple levels. In the presentation we detail the characteristics of classroom and whole school environments that provide productive and transformative learning identities for students, that position Black students as thinkers and learners, and that build productive and transformative caring relationships for students.

In particular, findings highlight three dimensions of successful classroom learning environments: 1) They employ new kinds of culturally-congruent disciplinary practices, 2) They debunk and reframe negative stereotypes about Black students, and 3) They attend to the building of multi-layered community relationships. With respect to the ways that whole-school settings support or challenge the creation of successful learning settings for African American students, emerging findings suggest that a shared mission on the part of school administrators and teachers, and attention to creating a whole school climate that centers creating supportive and engaging experiences for African American students, and explicitly countering dominant ideologies and practices are all critical aspects of successfully supporting African American learning. Implications for the design of learning environments are discussed.

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Vossoughi, S. & Gutiérrez, K. (In press). Studying movement, hybridity, and change: Toward a multi-sited sensibility for research on learning across contexts and borders. *NSSE Yearbook. Designing educational programs with children and youth: Alternative & flexible contexts for learning.*

# Combining Video Games and Constructionist Design to Support Deep Learning in Play

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**Abstract:** In recent years much research has explored the potential of using video games in education. This effort has produced many interesting games though it is unclear if “educational video games” have achieved their promise. Similarly, for many years constructionists have engaged children in learning across a variety of contexts, including game design. While these programs have been successful, their exploratory nature leads to concerns about content coverage. In this symposium we discuss the potential of blending these two design traditions. Constructionist video games infuse traditional game structures with constructionist ideals to create gaming experiences that encourage exploration while ensuring engagement with desired content. This symposium presents the constructionist video games construct and showcases empirical research on the use of such games in both formal and informal contexts.

## Session Summary

In this symposium we bring together researchers from the educational games and constructionist design communities to discuss empirical work highlighting the value and challenges of merging these two design traditions.

Recent data suggests 97% of all children play video games daily (Lenhart et al., 2008). As a nearly universal experience for American youth, video games offer an exciting design opportunity with the potential of having immense impact. In the past decade there has been a large influx of effort and money to take advantage of this opportunity and design video games that offer powerful educational experiences. This effort has produced many interesting products that wrap school-sanctioned content inside traditional game mechanics and structures allowing learners to interact with targeted lessons in a highly engaging format. While there has been considerable enthusiasm for this program of research and the results suggest learners improve on metrics directly aligned to in-game action, learners often fail to acquire a deep understanding of embedded content that they can apply in alternate contexts (Annetta, 2008; Barab et al., 2007; Clark & Martinez-Garza, 2012).

At the same time, researchers firmly rooted in the constructionist design tradition (Harel & Papert, 1991; Papert, 1980) have produced a host of environments that allow children to create games of their own design (Caperton, 2010; Kafai, 1995). This work has proven successful at achieving deep learning in a wide variety of domains, but is often hampered by its own commitment to openness when attempting to focus learners on specific ideas or content. The challenge, referred to by Noss and Hoyles (1996) as the “play paradox,” is to create an effective balance between designs that force learners to confront targeted content (which in turn may reduce the feeling of play), versus those that provide complete freedom in exploration (sacrificing assurances that learners will *always* encounter the targeted content).

The blended genre of constructionist video games has been proposed as an approach that can overcome the challenges faced by each design perspective in isolation. Constructionist video games (Weintrop, Holbert, Wilensky, & Horn, 2012) infuse traditional video game structures with constructionist ideals and mechanics to create gaming experience that encourage exploration and experimentation while ensuring players’ engagement with prescribed ideas and content. This design approach is particularly suited to deepen learners’ experiences with mechanics in educational video games though it also shows potential for streamlining exploration in fully

constructionist spaces. In this symposium we present the constructionist video games construct, discussing both its historical roots as well as areas where we believe the construct forges new territory, and showcase empirical research on the use and potential of such games in both formal and informal contexts.

The symposium will consist of four presentations. Nathan Holbert, David Weintrop, and Uri Wilensky will open the session by presenting the constructionist video games construct. This talk will highlight the various principles important to the design of constructionist video games and showcase findings from two such games, *RoboBuilder* and *Particles!*, that highlight the potential of this design for producing powerful play experiences that result in deep learning. Pratim Sengupta, Stephen Killingsworth, Kara Krinks, Corey Brady, and Douglas Clark will present SURGE, a game for exploring Newtonian Mechanics that blends the important practice of scientific modeling with video game play. This talk reports findings from a study of 7<sup>th</sup> graders playing SURGE to show how interactions with the constructionist designs in the game supported students as they made sense of Newton's 1<sup>st</sup> and 2<sup>nd</sup> laws. In the third talk, Eric Klopfer presents a new massively multiplayer constructionist game, *Radix*, for learning science and math and shows how the open nature of *Radix* supports learners as they engage in authentic science inquiry. In the final presentation of the symposium, R. Benjamin Shapiro and Rosemary S. Russ, describe how cognitive clinical interviews enabled an evaluation of the design of a constructionist video game designed to engage players with issues of sustainability. Shapiro and Russ present evidence from a series of clinical interviews conducted with game players showing that participants often reevaluated their assumptions about sustainable framing practices through the new perspective acquired from game mechanics. Finally, acting as the session discussant, Yasmin Kafai will bring her expertise both as a leading constructionist theorist and designer as well as her many years studying how children learn while playing and making games to review some of the overlapping issues brought up by session presentations and to highlight the potential advantages and disadvantages of this design approach.

## **Constructionist Video Games: Creating Educational Video Games that Empower Players to Construct New Knowledge**

Nathan Holbert, David Weintrop, and Uri Wilensky

### **Objective**

This talk will lay the theoretical groundwork for the design genre of constructionist video games and, using environments of the authors' designs, discuss the major features and principles of this class of learning environment. As described in the session summary, constructionist video games merge features of video game design with educational theory and design principles from the constructionist tradition to form a medium that supports meaningful exploration and learning while also providing a motivating, structured learning context (Weintrop, Holbert, Wilensky, & Horn, 2012). By blending these two design traditions we address what Noss & Hoyles (1996) call the 'play paradox'; the tension between allowing open, learner-directed exploration and the desire on the part of the designer for the learner to engage with the content designed into the environment.

We define constructionist video games as: *Designed computational environments in which players construct personally meaningful and shareable artifacts to overcome artificial conflict or obstacles resulting in a quantifiable outcome*. To aid in the construction of these games, we offer four key design principles:

1. Constructionist video games include sufficiently expressive construction tools with which players can engage in personally meaningful ways.
2. Game goals and construction tools encourage exploration and discovery during play.
3. Constructionist video games provide a public forum for players to share constructed artifacts with others.
4. Learners engage with and employ one or more powerful ideas to advance through the game.

We have been motivated by the sense that traditional educational video games often focus too intently on *delivering* content, and not enough on *empowering* players to construct new knowledge that they find personally meaningful. As knowledge construction is a strength of the constructionist program, we have worked to find innovative ways to bring constructionist principles to the design of educational video games. In this talk, we present two such attempts: *RoboBuilder* and *Particles!* (Figure 1.). Using these games as "objects-to-think-with" (Papert, 1980) we will elaborate on the four design principles central to creating constructions video games. We will then briefly report findings from two empirical studies to show how these principles provided opportunities for learners to engage deeply with target concepts intentionally embedded in the games as well as evidence indicating that players gained new knowledge resources for thinking and reasoning outside of the game.



**Figure 1.** In *Particles!* (a) players design molecules for blocks that can be added throughout the game to change the emergent physical properties of objects in the game world. In *RoboBuilder* (b) players construct a robot strategy in a block-based language then watch their robot enact it in competition.

## Theoretical Framework

The constructionist video game construct is rooted in the constructionist design approach (Harel & Papert, 1991; Papert, 1980) and engages players in the construction of personally meaningful artifacts. This construction process facilitates the development of internal cognitive structures and brings learners into a closer relationship with explored ideas, phenomena, and systems (Papert & Harel, 1991; Wilensky, 1991). We also draw from the growing literature on the use of video games as contexts for learning, including their potential as motivating environments, their alignment with youth identity and norms, and their potential to enable new, interactive engagement with concepts (Annetta, 2008; Barab et al., 2007; Gee, 2003). To evaluate the formation and character of constructed knowledge structures, we draw heavily from the knowledge-in-pieces theory of cognition which views cognition as an emergent process heavily determined by the tools, resources, and implied perspectives provided by the situational context (diSessa, 1993).

## Methods and Data

This talk will incorporate data from two separate studies of participants playing an author-designed constructionist video game. In the first study, we draw on data collected from a study of 15 programming novices playing *RoboBuilder* (Weintrop & Wilensky, 2013). In *RoboBuilder*, players write small programs using a domain-specific, visual programming language to control an in-game character as it does battle. During gameplay, subjects were instructed to think-aloud and were asked summative questions by the researcher about their experience at the conclusion of game play. Additionally, artifacts constructed in-game were collected for later analysis. Data from the study in the form of vignettes, programs constructed, and post gameplay interviews will be presented to show how *RoboBuilder*'s construction primitives allowed players to externalize their design ideas for further evaluation and debugging.

In the second study we present data from nine children, ages 11-14 playing *Particles!* (Holbert & Wilensky, 2012). *Particles!* is a platformer game intended to help players see how the properties of objects in the world emerge from the arrangements and structures of atoms and molecules. In *Particles!* players are given the opportunity to modify game levels as they play through them by dynamically designing the molecular-level structures that make up game blocks which in turn leads to blocks with new emergent properties. Players were interviewed before and after playing the game about the properties of real world objects. An analysis of player responses will be used to show how *Particles!* players drew on in-game representations to provide more precise and complex explanations for the causes of material properties.

## Results

In our presentation we will outline the central characteristics of the constructionist video game genre and show how each feature was incorporated into *RoboBuilder* and *Particles!*. We will then show how these features became the central mechanism by which players encountered targeted concepts and used these concepts both in and outside of the game to think and reason about related phenomena.

In the case of *RoboBuilder*, this takes the form of players developing an understanding of central programming concepts through their iterative development of in-game robot strategies. Over the course of gameplay, data shows the novice programmers constructing strategies of increasing size and sophistication as they progress through the game. Further, in analyzing the interviews, we find evidence of players engaging with the concepts designed into the game, including the relationship between the programs and the resulting behavior, and the ways conditional logic, iteration, and state can be used to create desired in-game behaviors.

For *Particles!*, pre- and post-game interviews reveal players shifting from attributing object properties to the identity of the substance the object is made of to descriptions that attend to the arrangement and structure

of the particles that make up each object. These more complex and precise descriptions of the cause of object properties were paired with references to in-game construction tools indicating these shifts were likely due to interactions with the constructionist features of the game.

## Significance

Given the prevalence and popularity of video games in youth culture, the potential impact of fun, engaging, and most importantly, effective educational video games grows. Built off a firm theoretical grounding and backed by evidence of the successes of environments designed in this genre, the spread of constructionist video games has great potential for influencing the designers of learning environments and enabling deep, meaningful learning to happen through the increasingly popular act of playing video games.

## Integrating Modeling with Games for Learning Newtonian Mechanics

Pratim Sengupta, Stephen Killingsworth, Kara Krinks, Corey Brady, and Doug Clark

### Introduction

Modeling is the language of science, and development of scientific expertise is inseparably intertwined with the development of epistemic and representational practices such as modeling and graphing (Giere, 1988; Lehrer & Schauble, 2006; Nersessian, 1992). In this paper, we focus on the integration of modeling with digital games for learning physics. We show how the integration of graphing and modeling with SURGE as core gaming activities positively effects students' learning of concepts related to Newton's first and second laws that have been traditionally challenging for novices to learn (Halloun & Hestenes, 1985; Larkin et al., 1980; Dykstra & Sweet, 2009).

### Modeling and Graphing in SURGE

SURGE (Figure 2) supports students' game play as an iterative process of modeling. In order to make Surge move along a path, the learner creates a predictive model of the trajectory, by placing impulses along the target path. The learner then deploys his or her model by playing the level, which simulates the behavior of Surge on-screen. Feedback enables learners to refine and revise their initial models.

In addition, a graphing environment enables real-time construction of representations based on periodic sampling of measures of SURGE's motion (including total displacement; signed x- and y-component displacements; total velocity; and signed x- and y- component velocities). A slider-bar on the x-axis allows the student to rewind and replay the completed level.

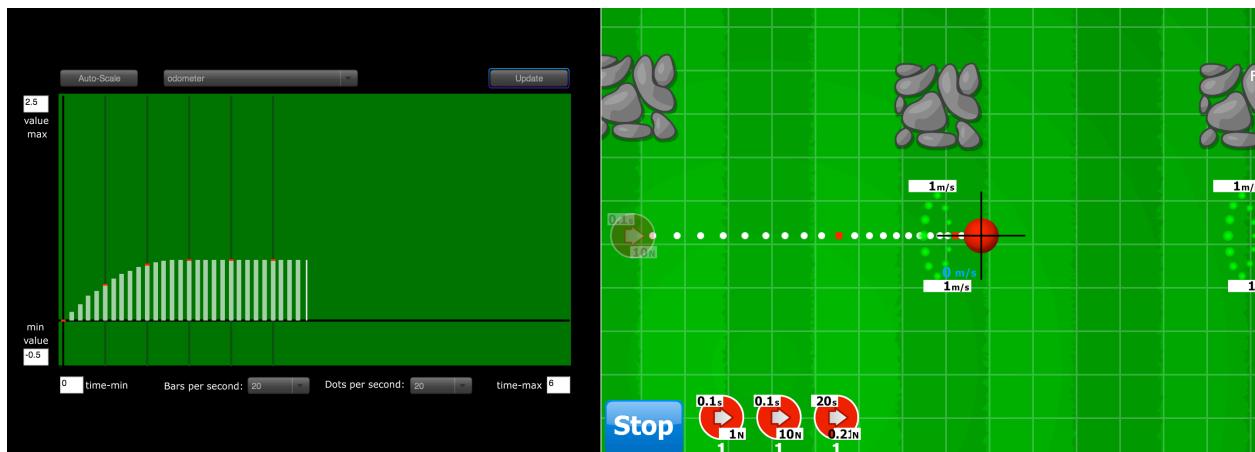


Figure 2: SURGE's world (on the right) and the graphing environment (on the left)

### The Study and Findings

We conducted a study in which four sections of 7th grade students in a public school in Nashville interacted with SURGE. Students within each class were randomly assigned to one of two graphing conditions (grapher vs. no grapher) and one of two collaboration conditions (collaborative vs. non-collaborative). Repeated-measures ANOVAs were conducted for each of three question groups (Newton's 1<sup>st</sup> Law Questions, Newton's 2<sup>nd</sup> Law Questions, and Graphing Questions). Across the between-subjects conditions, the analysis showed significant pre-post gains for the Newton's 1<sup>st</sup> Law,  $F(1, 96) = 87.42$ ,  $p < .0001$ ,  $\eta^2 = .07$ , and for the Newton's 2<sup>nd</sup> Law questions,  $F(1, 96) = 6.05$ ,  $p = .02$ ,  $\eta^2 = .06$ . There were not significant gains overall for the graphing questions,  $F(1, 96) = .51$ ,  $p = .48$ ,  $\eta^2 = .01$ , but there was a marginal interaction between graphing condition and test

administration for questions on Newton's 2<sup>nd</sup> Law questions,  $F(1, 96) = 2.87$ ,  $p = .09 = .03$ . This interaction suggests that the graphing activity may have allowed students to perform better on 2<sup>nd</sup> Law questions ( $M_{\text{gain}} = 11.1\%$ ,  $SD_{\text{gain}} = 25.3$ ) than without the grapher ( $M_{\text{gain}} = 3.1\%$ ,  $SD_{\text{gain}} = 27.0$ ). We will also present qualitative case studies of students based on video data, which illustrate the process through which this improvement may have occurred.

### Scholarly Significance

Given that models and modeling are central to informal game play (Gee, 2006), we present a pedagogical approach in which modeling and graphing can be integrated as core game-playing activities to support conceptual development in physics. Our findings highlight the importance of supporting the development of students' representational competence central to Newtonian mechanics in order to support their conceptual development.

## Constructivism, Constructionism and The Radix Endeavor

Eric Klopfer

### Objective

For years the Scheller Teacher Education Program (STEP) has been developing constructionist environments to promote STEM learning. These environments have included tools for developing 3D games and simulations (StarLogo TNG). In recent years work has focused on combining game development and simulation use (Klopfer et al. 2009). However, these open-ended tasks often face an implementation challenges in classrooms. In parallel STEP has been developing educational games that embody some of these same characteristics. The latest game, The Radix Endeavor (Radix), is a Massively Multiplayer Online Roleplaying Game (MMO), which allows players to be self-directed, while bounding their actions and focusing them on mastery of science and math concepts.

### Perspective

A radical constructionist (Papert & Harel 1991) game is hard to conceive, at least by many definitions of games that imply particular goals and constraints. But different games can include components of constructionist design in interesting ways. MMOs, in which players explore a large world, obtain a variety of quests that they can complete in increasingly more complex chains, and center around tool use allow for a great deal of player choice and customization. This design is consistent with Experiential Learning (Kolb 1984) in which learners/players have experiences (engage in game play), reflect on those experiences (often through lulls in the game between increasingly challenging quests – sometimes with other players in the world), abstract those ideas (in order to be able to apply them in new situations) and test them (through the next task).

### Methods

Players in Radix choose a character that either pursues the biology line or the mathematics line. The premise of the world is that in a renaissance era earth-like world, math and science are being kept from the people by an evil ruler. The player takes on the role of an apprentice in an underground society attempting to bring this knowledge back to the people to help with a variety of world issues. Players obtain quests in the world, which require no previous knowledge but relate to core concepts in each of the associated domains. The key "weapons" that players have are scientific tools associated with each of the quest lines. Advancing in quest lines provides players with more sophisticated tools. In many of the quests they are changing the world through environmental improvement or constructing buildings.

### Data Sources

As players proceed through quests in the world, data is tracked from each of their tasks, noting how often they try a task, and diagnosing where they succeed and fail. The game provides feedback to the players about where they are struggling, but does not provide direct instruction. In this study, data is obtained from both in game data, and external content assessments aligned with state standards.

### Results and Significance

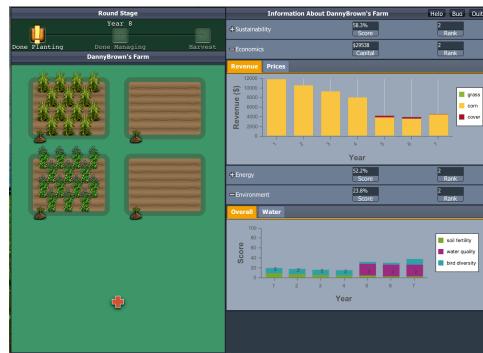
Players in Radix have shown a propensity for exploring many of the more open-ended areas of the world, even when the game provides little to no direction in that exploration. The quest design and tool use have successfully embodied the experiential learning approach.

## Cognitive Clinical Interviews for Studying Thinking in Constructionist Video Games

R. Benjamin Shapiro and Rosemary S. Russ

Supporting the development of robust, multi-faceted understandings of sustainability along with the system-level dynamics and individual-level choices that give rise to it is a difficult design research problem (Goh et al., 2012; Eberbach et al., 2012). One element of this challenge is that sustainability is a compound outcome; it can be quantified as a weighted sum of environmental, social, and economic sustainability measures that themselves exist at both local and global levels of scale (Gratton, 2011). Additionally, the measures are interdependent; an individual farm that minimizes adverse environmental impact cannot be said to be sustainable if the means through which it does so render it economically insolvent.

Role-playing video games, essentially participatory simulations (Wilensky & Stroup, 1999) with a playful, role-based twist, provide opportunities for players to learn interconnections between individual choices and local/global sustainability processes and outcomes. We created a multi-player video game in which participants role-play as farmers by making choices about what biofuel crops to plant in their fields over time given shifting market conditions (Figure 3 shows a screen shot of the most current version of the game). Throughout multiple “years” (rounds) of play, farmers design and tinker with their fields based on their understanding of how the global system works and how to succeed in that system. That is, they make decisions on how to construct their overall farm (i.e. the ways that particular fields are planted, fertilized, or left fallow) based on their interpretations of the external, shared representations of the global environmental and economic system. It is in this sense that the game reflects the principles of constructionism (Papert, 1990; Shaw, 1996).



**Figure 3.** Screen shot of player “DannyBrown”’s farm after 7 “years” of playing the game.

We conducted game-play sessions in undergraduate classrooms to investigate how game play, combined with peer and whole class discussions enabled learners to reason about the system dynamics of the simulated game world, and how individual’s choices could respond to or shape them. These sessions mirrored how we expect the game will typically be used in schools, and so were of 1-2 hours in duration. Consequently, students were only able to play through a limited number of scenarios, limiting our ability to observe how students might reason about and respond to important conditions.

Therefore, play sessions were followed by cognitive clinical interviews (Ginsburg, 1997) that asked participants to explain how individual choices or aggregate patterns cause various non-game-based scenarios, or to explain what they would do in various scenarios, and why. Our choice to use cognitive clinical interviews to assess learning was deliberate; they offer the opportunity to probe the structure and robustness of learners’ conceptual models developed through constructionist game play.

Analyses of these interviews revealed that participants generally understood causal mechanisms embedded in the game’s simulation, connecting soil health, short- and long-term profit, the impacts of bioenergy producing crops, supply and demand, and how individual values shape choices. Some participants explained ways in which their own beliefs about those value-laden priorities shifted as a result of game play and discussion, and how those shifts were operationalized in their game play choices. Finally, participants successfully transferred their newly developed understanding of bioenergy farming sustainability dynamics to hypothetical scenarios outside of the game context. Many of these nuanced understandings were not apparent during the limited time that game play was possible in a classroom setting, and so could not be observed through play alone. By using cognitive clinical interviews we were able to develop insights into student thinking that would otherwise have been invisible.

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# Disrupting Learning: Changing Local Practice for Good

**Chair:** Jasmine Y. Ma, New York University, j.ma@nyu.edu

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**Discussants:** Rogers Hall and Melissa Gresalfi, Vanderbilt University  
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**Abstract:** The papers in this symposium explore the concept of disruptions as an analytical concept for investigating how individual learning and changes in local practice mutually influence each other in designed learning contexts. Disruptions are rearrangements, temporary or sustained, of typical practice, meaningfully experienced by participants. The papers present data from a variety of studies investigating middle and high school mathematics education settings (teacher professional development, a geometry design study, museum field trips) as comparative cases for exploring the idea of disruptions. We explore how disruptions to typical practice in terms of discourse, authority, participation frames, material and representational tools, and spaces and modes of learning are taken up, adapted, or rejected by learners, and how this informs design.

## Symposium Overview

Sociocultural theories of learning value the contexts (e.g., Greeno & MMAP, 1998; Rogoff, 2003) or communities of practice (Lave & Wenger, 1991; Wenger, 1998) where learning occurs, but ways of understanding individuals' learning in concert with changing practice are still under development (Cobb, Stephan, McClain, & Gravemeijer, 2001; Engeström & Sannino, 2010; Hall & Greeno, 2008). This problem is particularly salient in settings designed specifically for learning, where students and teachers are developing their own practices within the learning context.

The papers in this symposium explore the concept of *disruptions* as a productive analytical concept for investigating how individual learning and changes in local practice mutually influence each other in designed learning contexts. We view disruptions as rearrangements, temporary or sustained, of typical practice, meaningfully experienced by participants. In general, disruptions may originate unexpectedly from external sources (e.g., an unscheduled fire drill during class, Rosebery, Ogonowski, DiSchino, & Warren, 2010), emerge from the needs or routines of ongoing practice (e.g., groups from different scientific disciplines interact to create new methods of analysis, Hall, Stevens, & Torralba, 2002), or result from designed interventions (e.g., leveraging rather than silencing students' counterscripts in classroom instruction, Gutierrez, Baquedano, & Tejeda, 1999).

Each of the papers presented here address disruptions that were created explicitly by design, targeted the norms and practices of typical classroom mathematics, and had diverse results for participants, their activity, and our understanding of their mathematics activity and learning. The authors all treat their study sites as intact activity systems, and the disruptions as consequential to how participants have access to and engage in the practices of these settings, and their learning. The findings from these papers, and the discussion following their presentation will contribute to theories of disruptions or changes in practice, and raise implications for the design of learning settings.

In the first paper, Munter, Heyd-Metzuyanim, and Greeno describe an episode of professional development and the resulting lesson of an algebra 2 teacher. The teacher attempted to disrupt the prevailing authority norm in the class by not telling whether the students were right or wrong. The authors found that this disruption was largely resisted by students, and was perhaps incompatible with other, aspects of the classroom setting that were left intact. In the second paper, Ma reports on a design which relied on a disruption to geometry's typical paper-and-pencil scale to strip the seventh grade class setting of established school mathematics tools and embodied dispositions, inviting students to engage out-of-school resources for learning and doing mathematics. She describes some ways in which this disruption supported a hybrid learning setting where students invented new tools for geometry problem solving, but also interrogates tensions and missteps that arose in the design and implementation. Finally, Kelton investigates middle school mathematics classes' field trips to a museum mathematics exhibit called *Math Moves!*, that explores ratio and proportion. These field trips are disruptions to school mathematics in the sense that the routines and spaces of schooling change, but the

exhibit itself disrupts the formalisms and representations of classroom mathematics in favor of multi-modal and multi-party explorations. She considers how the disruptive qualities and characteristics of this field trip and the exhibit flow into classroom learning, sometimes even before the visit itself.

By treating various aspects of designed mathematics learning settings as disruptions, this collection of papers provides a diverse set of cases for comparing and contrasting some possible types of disruptions, different dimensions (borrowing from Munter et al.'s paper) of classroom mathematics that might be disrupted, how they reorganize (or fail to reorganize) activity, and how they change individuals' participation and learning. This symposium will include three paper presentations, and comments from two discussants, Rogers Hall and Melissa Gresalfi. Hall's extensive work on disruptions in professional workplaces and the interactions between professional disciplines (e.g., Hall & Horn, 2012; Hall, Stevens, & Torralba, 2002) will provide a contrasting perspective from Gresalfi, whose research is more focused on classroom settings, and takes a sociocultural perspective in considering issues of mathematics disposition and identity, opportunities to learn, and equity (e.g., Gresalfi, 2009; Gresalfi & Cobb, 2011). There will also be time for audience-driven discussion.

## Designing for Disruption Through Misaligned Frames

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Classroom life is usually a highly stable and routinized type of social practice (Cazden, 2001; Mehan, 1979). Though the teacher may be one of the leading agents that can influence it, it also has 'a life of its own' in the sense that it encompasses the whole set of expectations of the students, and the ways that they have become used to participating in the social activity called 'a mathematics lesson.' Although the differences in authority distribution between different instructional models (e.g., direct instruction or dialogic instruction) is fairly clear, how teachers and students make the transition from one to the other is not (Adler, Ball, Krainer, Lin, & Novotna, 2005; Goldsmith & Schifter, 1997; Staples, 2007). What is certain is that the transition is challenging (Hufferd-Ackles, Fuson, & Sherin, 2004), in part because the attribution of mathematical authority is just one in a complex system of variables, including the nature of classroom discourse (likely driven by teachers' questions, at least initially) and the nature of mathematical tasks—all situated, of course, in a broader social and cultural context (Depaepe, De Corte, & Verschaffel, 2012). And, shifting the distribution of authority likely requires disrupting all classroom participants' expectations for the roles that students and teacher will play—which become increasingly ingrained with each school year (Hammer, Elby, Scherr, & Redish, 2005).

In this paper we examine the attempt of one U.S. public high school mathematics teacher (pseudonym Mrs. Q) to disrupt the "authority norm" (Depaepe et al., 2012) during one lesson in her algebra 2 classroom—an act that was the result of her professional development and co-planning work with the first author (Chuck). Of course, significant shifts in students' expectations for how they will do things in the classroom are not likely achieved in a single day. But, by all accounts—both the teacher's and ours—the lesson was not even the modest success that it was imagined in planning. To explain that result we examined two sets of interactions—those between the students and Mrs. Q (during the lesson), and those between Mrs. Q and Chuck (during the lesson planning) with respect to how individuals were framing (Hammer, Elby, Scherr, & Redish, 2005) their roles, the mathematical tasks, and the intent and nature of classroom discourse.

In the second half of the 2012-2013 school year, Chuck began working with Mrs. Q, a high school mathematics teacher in her ninth year at the school, on identifying ways to employ more Accountable Talk (Michaels, O'Connor, & Resnick, 2008) in an algebra 2 classroom comprised of students who had previously been identified as struggling and assigned to a 'double-block' (90 as opposed to 45 minutes) mathematics class. The professional development (PD) consisted primarily of co-planning, reflecting on the execution of lessons, and examining transcript from MRS. Q's lessons.

During the third PD session, after analyzing a transcript from a previous class, Chuck asked MRS. Q whether she finds that her students often ask her if their solutions are correct. She responded that her students do it "constantly," suggesting (and lamenting) that they want immediate validation or they will stop working, and that "we as educators must have taught them to do it"—through teacher-centered instruction, "we've made them insecure as to what they're doing. They're going to feel like they're always wrong." In response to what she had identified as a challenge in her class's patterns of discourse and what she perceived as her students' expectations regarding her role, Chuck challenged her to attempt to refrain from telling students whether they are right or wrong. She said she would try, but predicted that she would have "mutiny" since the students would view her attempt to disrupt the authority norm as "not teaching." This episode set up the two episodes that were the foci of our analysis.

We (the researchers) analyzed transcripts from audio recordings of two sets of interactions—the fourth professional development/planning session on Monday, February 18 and the lesson on the following Tuesday. In the first, Mrs. Q and Chuck co-planned a lesson that would focus on identifying the zeroes of polynomial

functions (with an emphasis on factoring). For the day's primary task, they chose "What are the zeroes of  $f(x) = 6x^3 - 19x^2 - 9x + 36$ ?"—which, in factored form, is  $f(x) = (x - 3)(2x - 3)(3x + 4)$ —and identified at least two strategies that students would likely employ (trial and error and graphing it on a calculator to find x-intercepts). They imagined that, employing either of those methods to find an initial root, students might then write a factor 'around' that root and use long division to rewrite  $f(x)$ , e.g.,  $f(x) = (x - 3)(9x^2 + 6x - 12)$  (a procedure that Mrs. Q had demonstrated in the previous day's lesson). In order to set up that group work and the eventual discussion of students' strategies, Mrs. Q and Chuck decided that the warm-up launch would include asking students to "find the zeroes of the quadratic function by factoring:  $g(x) = x^2 - 7x + 12$ ," to promote factoring polynomials for a purpose (finding the roots) and to increase the likelihood that students would write a binomial factor for the first root they identify in the day's primary task (likely  $x = 3$ ).

In the lesson, Mrs. Q posed a slightly modified version of the planned warm-up task: "Solve  $x^2 - 7x + 12 = 0$ ." When some of the students used the quadratic formula, Mrs. Q took the strategy up for the whole class, prompted them for which numerals to write where and the results of each calculation, and arrived at the solutions, which Mrs. Q told them are also referred to as "roots" or "zeroes."

After similarly completing two more warm-up tasks that Mrs. Q and Chuck had planned, Mrs. Q asked students to work on the day's primary task in groups. During that 45 minutes of group time, students made little, if any, progress in solving the task. At one point, Mrs. Q visited a group whose idea was to use the quadratic formula. She said, "this is called the quadratic formula, so it has to be used for a quadratic equation. Is that a quadratic equation which I gave on your paper?" and then asked what they might do instead. When the students remained puzzled, she continued:

- MRS. Q: You've not done this before. I'm trying to get you to use your tools to hook 'em all together, to be able to do this.
- FS: You should give us an example.
- Mrs. Q: Well, then I'm not trying- I'm not getting you to *think*. You're trying to find the zeros so what does it mean- I'm gonna address all, all, three groups, okay? [To the whole class] On this problem, I'm not telling you how to do it, okay, and you haven't done one precisely like this, so... You're tryin to find the zeros. I'm not asking for an answer right now, I'm asking you to think, "What does it mean to be a zero of a function?" You can think back to the warm up, you can think back to different things... What does it mean if something is a zero of a function? (7 sec.)
- MS: Uh... X?
- Mrs. Q: I'm not asking you for an answer, I'm trying to get you to think about it so you can start answering this problem.
- Mrs. Q: [15 seconds later, repeated question for one group] What does it mean to be a zero of a function?
- MS: Zero.
- MS: Nothin'.
- MRS. Q: Okay, zero is an answer, sure. What, okay, so, what does a zero look if you have a graph? Where do you find them?
- Chris: Uh, right and left.
- MRS. Q: Okay. So, you're trying to find the zeros of that function. What kind of function is that on your paper?
- Chris: A polynomial.
- MRS. Q: It *is* a polynomial. Absolutely. What degree is that polynomial on your paper?
- Chris: Um... cubed?
- MRS. Q: Okay, so how many- how many zeros should you have?
- Chris: Three.
- MRS. Q: Okay. So, can you think of a way to find *any* of them?
- Chris: Uh, don't we got- uh, we got the zero property, uh, to get three zeroes.
- Matthew: I don't know, Mrs. Q, you gotta help us.

Mrs. Q provided hints (e.g., "What degree is that polynomial?... so how many zeroes should there be?" "If you graph it, don't you think you can find a root by the same procedure [as in the warm-up]?"") until the students graphed the function and identified  $(3, 0)$  as one root. Then after more hints, Matthew divided  $f(x)$  by  $(x - 3)$ , Mrs. Q suggested that others do that, and students struggled to do so, until Mrs. Q posed the 'exit slip' task with two minutes remaining in the lesson, with no discussion of strategies, or even a statement of the solutions to the day's primary task. Throughout the lesson, students complained about Mrs. Q not telling them if they're right or wrong and not giving them examples of solutions that they could follow.

In our analysis of transcript of the preceding day's PD session, we used the notion of 'frames,' borrowed from sociolinguistic and situated cognition research (Hammer, Elby, Scherr, & Redish, 2005; Tannen, 1993). Hammer et al (2005) defined frames as "an individual's interpretation of 'what is going on here'" (p. 98). In their co-planning, we looked for evidence of Mrs. Q's and Chuck's interpretations of 'what is supposed to go on there [in the classroom].' In examining this lesson, and in particular in trying to understand what went wrong (or differently than envisioned in the planning session), we considered three dimensions of the classroom activity system drawn from research in mathematics classrooms: distribution of authority (Lampert, 1990; Rogoff, Matusov, & White, 1996); the nature of classroom discourse (Thompson, Philipp, Thompson, & Boyd, 1994); and the nature of the mathematical tasks (Stein, Grover, & Henningsen, 1996; Smith & Stein, 1998)—each with distinct 'opposite ends' representing different forms of instructional practice or epistemic stances about mathematics, between which are points of transition.

In line with Rogoff et al.'s (1996) perspective, we viewed a transition along the first dimension, distribution of authority, as a shift from approaching classroom learning as a one-sided process (either adult-run or children-run—but, in this case, most likely the former) to a shared endeavor in which teacher and students mutually engage. For the second, classroom discourse, we draw on the work of Thompson et al. (1994), who articulated different orientations in the discourses of two teachers' classrooms—calculational and conceptual. "The first teacher's goal was for students to solve the problem and share their procedures; the second teacher's goal was to create an occasion for students to reason and to make their reasoning public" (p. 87). We viewed the last dimension, mathematical tasks, as a potential shift from "low-level" to "high-level" tasks as defined by Stein and colleagues (Stein, Grover, & Henningsen, 1996; Smith & Stein, 1998), where the former includes tasks aimed at memorization or fluency with procedures but without making conceptual connections, and the latter includes tasks that promote understanding procedures conceptually or provide opportunities to solve challenging, ambiguously defined problems without the suggestion of a particular procedure or path to a solution.

We concluded that Mrs. Q's disruption was along only one of the three dimensions described above—the distribution of authority. The role in determining correctness had been shifted, but the tasks remained focused on using procedures to produce solutions, and the talk about the work remained calculational in nature. For example, instead of posing the first task as planned, "Find the zeroes of the quadratic function by factoring:  $g(x) = x^2 - 7x + 12$ ," Mrs. Q. asked students to "Solve  $x^2 - 7x + 12 = 0$ ." The planned version was intended to afford opportunities to make connections between a graphical representation of the functions roots and making sense of two factors' product being zero (often referred to in Mrs. Q's classroom as "ZPP," or the "zero product property," which Chris was referencing in the transcript above). But the restated version oriented students to using a different procedure—the quadratic formula, which did not provide an opportunity to use factors, and could not be used (as a first step) on the cubic later, though some students thought it could. Without concomitant shifts in these other, related dimensions of the classroom activity system, what was previously a relatively coherent system was rendered non-sensible by an attempt to disrupt the authority norm, particularly from students' perspectives (e.g., "You should give us an example"; "Mrs. Q, you gotta help us").

The other layer of our analysis revealed that the lack of success of the disruption was attributable, in part, to a misalignment in the ways that Mrs. Q and Chuck had framed the lesson. Similar to the distinction quoted from Thompson et al. (1994) above, Chuck's view of what was supposed to go on was a sense-making endeavor, in which students would draw upon current resources to generate strategies for solving a problem—one that promoted making conceptual connections. For this, students would need to be supported in engaging meaningfully in the tasks through talk of a conceptual (and not merely calculational) orientation, including ensuring that students understood what the problem was asking (e.g., a brief conversation about what "zeroes" are; Jackson, Garrison, Wilson, Gibbons, & Shahan, 2013). On the other hand, Mrs. Q likely framed the lesson as a series of activities through which students would formalize a procedure for identifying the (real) roots of a polynomial function. Within such a framing, Mrs. Q's task and talk choices make sense, revealing the incompatibility of the disruption with both the other dimension of the system and with Mrs. Q's frame.

## Disruptive Scales in 7th Grade Geometry: Designing for Productive Hybridity

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In this design study a class of 7<sup>th</sup> graders constructed and worked with geometric objects at large scale, outside on a soccer field, using everyday materials such as ropes and lawn flags. The instructional setting was called "Walking Scale Geometry" (WSG). The premise behind the WSG design was that students learn mathematics best when they can connect to and build on prior experiences and knowledge (Civil, 2002; Gravemeijer, 1999), and that these should include both in- and out-of-school "funds of knowledge" (González, Andrade, Civil, & Moll, 2001) or "repertoires of practice" (Gutiérrez & Rogoff, 2003). From here on, I will refer to these simply as "resources." Instructional settings that incorporate and leverage students' recruited resources are often described by researchers as *hybrid*—classroom and disciplinary practices interface with home or community

practices to produce a new, transformative learning setting (Gutiérrez, Baquedano-López, & Tejeda, 1999). Moreover, when instructors are careful to design learning settings that leverage students' known (by instructors) or unexpected resources, these settings become more productive for all students' learning, since they are able to make their own sense of content (Calabrese Barton & Tan, 2009; Rosebery, Ogonowski, DiSchino, & Warren, 2010; Wager, 2012). One struggle that researchers have found in trying to design these productive, hybrid settings is that it is often difficult to make sensible (to researchers, teachers, and students) connections between out-of-school practices and the disciplinary objectives of the classroom (Civil, 2002; Wager, 2012). Additionally, in implementing these learning settings, some have found that students are often reluctant to, or simply do not recruit and deploy these out-of-school resources (Moje et al., 2004).

WSG was designed based on the theoretical view that, through their sustained participation in the mathematics classroom settings, many students have come to understand the world of mathematics and mathematics learning as one that does not include making connections to out-of-school life (Civil, 2002; Holland, Lachicotte, Skinner, Cain, 1998). They interpret mathematics problem solving as an isolated classroom or disciplinary activity with a set of rules determined by other more knowledgeable authorities, and these rules are not always transparent or understandable to them (Boaler & Greeno, 2000; Schoenfeld, 1988). They no longer expect the reasoning they do in school mathematics to have any relationship with the kinds of sense-making they do outside the mathematics classroom. Even when they engage in mathematical activity outside the classroom, students (and their families) often do not view it as mathematics (Goldman & Booker, 2009).

The WSG design took a tack different from previous studies in supporting hybridity by deliberately disrupting existing aspects of classroom mathematics instruction. Instead of designing instruction that bridged students' out-of-school resources with school mathematics learning goals, WSG hoped to invite students to recruit sensible (to them) resources by making unavailable some of those previously imposed on them by school mathematics. The goal of the design was for *productive hybridity* to emerge: the transformed context would contain elements of typical school mathematics and students' own resources, and expand mathematics activity (Engeström & Sannino, 2010) in a manner conducive to the learning of all students.

The WSG tasks asked students to construct geometric figures and explore properties like congruence and similarity outside on a soccer field with ropes, lawn flags, tape, and other materials. The tasks were similar to activities that students had encountered in their typical mathematics instruction, but the physical disruption invited them to see and engage in the mathematics in new ways. By drastically changing the scale of typical classroom geometry, the WSG design disrupted the tools (material and conceptual) and perspective of geometry problem solving. Students no longer had paper, pencils, rulers, protractors, or compasses, and could no longer engage by filling out solutions to problems on, for example, worksheets. Instead, students were asked to reason with and about everyday material objects and their bodies, and find ways to represent and mathematize them on their school soccer field (Figure 1). In working with the geometric objects, students were much smaller in comparison to the figures, and they also had to view them from within, rather than from a birds-eye-view as they did when working at paper and pencil scale. This meant a figure looked significantly different to any individual, and students did not generally have the same view as others.



**Figure 1.** Five students work together to "construct" a WSG rectangle.

The study took place over a five week period in a 7<sup>th</sup> grade mathematics classroom in an urban public middle school. The lessons were designed by the research team in collaboration with the regular classroom teacher and the school's mathematics coach before and during the five weeks. The lessons were taught by the mathematics coach, in part outside on the school's soccer field, but also in the classroom when the weather prohibited outdoor activity or when the class came back together to discuss what they had done. The research team observed and occasionally acted as teacher's aides, mainly answering students' questions.

Data collected included observations of the class's typical activity before the design study began, as well as dense video, audio, and photographic records of WSG and related classroom activity. We collected student work artifacts as well as interviews with students after the lesson sequence. Ethnographic and micro-

ethnographic methods were used in analysis, focusing on how students made sense of the disrupted learning setting, how they negotiated and accomplished problem solving, and what resources were recruited.

In general, students did adapt and invent new tools (both material and representational) and strategies for solving problems. Most strikingly, they developed new inscriptional systems using ropes, lawn flags, and their bodies, and new strategies for constructing congruent and similar triangles and quadrilaterals. They recruited classroom mathematics knowledge as well as knowledge of the everyday materials and their bodies. While analysis could not illuminate *what* out-of-school resources students drew from in order to invent their new ways of constructing, manipulating, and reasoning about the geometric figures, it was clear that their engagements were much more complex than making use of classroom strategies and knowledge transplanted out onto a soccer field and applied at large scale with ropes. For example, one group of students trying to construct and verify that their angles were congruent in their rectangle began developing a tool that would measure the distance between the two sides of the angle at a fixed distance from the vertex.

However, we identified two major dilemmas during the study. One conjecture of the design was that, in the course of their engagements in the disrupted problem solving context, students would develop strategies that might produce the need for additional materials, and that they would nominate some meaningful resources. We found that students were reluctant to request materials to use in the WSG tasks in addition to those we provided initially. Instead, they developed their strategies around the constraints of the provided materials, and modified their strategies when the materials made them problematic. Secondly, as the research team and teachers designed tasks in the midst of the lesson sequence, we found it difficult to maintain or agree on a balance of disruptions and conventional school mathematics that would result in learning that the teachers and their school would value as learning. In disrupting classroom mathematics, we also had to be able to build on the students' engagements in WSG to develop more "recognizable" mathematics knowledge and practices. This issue may be attributed to the imaginations of designers or the skill of teachers, but still raises the question of how disruptive a learning design can be and still be acceptable for school learning? Alternatively, we might ask if it is worthwhile to disrupt what currently counts as acceptable mathematics school learning and objectives in exchange for a comparably rich and applicable set of mathematics practices that are more accessible and meaningful to heterogeneous student populations.

## **Unbounded Disruptions: How Experiences with Mathematics Exhibits Entangle with School and Everyday Life**

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Over the past 15 years, science centers and other informal learning institutions across the U.S. have been developing exhibitions about a wide variety of mathematical topics, including geometry, number, pattern, algebra, calculus, and ratio and proportion (Anderson, 2001; Cooper, 2011). A striking feature of many of these exhibitions is that their design poses a counterpoint to familiar images of school mathematics. For example, at *Design Zone*, a traveling algebra exhibition, visitors will be hard pressed to find references to formal symbolism and syntactic rules. At the traveling exhibition, *Geometry Playground*, visitors pass through a labeled entry advertising an experience with geometry that is "more than what you study in school," then enter an exhibition space free of the axioms and two-column proofs characteristic of high-school geometry. And *Math Moves!* – a permanent exhibition about ratio and proportion that is the focus of this study – conspicuously avoids mention of the cross-multiply algorithm that is the centerpiece of traditional curricular treatments of ratio and proportion. How are visitors to museums and science centers interacting with and making sense of mathematics exhibitions? And, given the apparent contrast between many of these exhibitions and traditional classrooms, how might mathematical learning experiences in museums and schools be related?

While the opportunities for engaging with mathematics in U.S. museums are expanding, to date only a handful of research and evaluation studies have investigated learning in these environments (Anderson, 2001; Cooper, 2011; Guberman, Flexer, Flexer, & Topping, 1999; Gyllenhaal, 2006; Mokros, 2006; Nemirovsky, Kelton, & Rhodehamel, 2012, 2013). Even less is understood about how learning at these exhibitions might relate to past or present participation in school mathematics (Gyllenhaal, 2006). This study explores this unmapped empirical territory by tracing the activities of teachers and students as they move between mathematics classrooms and the exhibition *Math Moves!* in the context of a school field trip.

*Math Moves!* is a suite of interactive exhibits that invite users to engage multiple perceptual modalities, employ whole-body motion, and jointly collaborate in a variety of open-ended activities broadly related to the mathematics of ratio and proportion ([www.mathmoves.org](http://www.mathmoves.org)). Museum professionals from four US science centers, as well as educational researchers, including the first author (Kelton), collaboratively designed the exhibition. Copies of the exhibition are now installed at each of the four contributing science centers, with each installation customized to fit the spaces and institutional cultures of the four organizations.

*Math Moves!* is the outcome of an intentional attempt by the designers to disrupt familiar images of school mathematics along multiple dimensions. Inspired by contemporary theories of embodied mathematical cognition and pedagogy (e.g. Hall & Nemirovsky, 2012), the design of *Math Moves!* stages a purposeful counterpoint to the scales and modalities of perception and movement characteristic of traditional school mathematics through technologies that emphasize wide ranges of both gross and fine motor action, whole-body immersion, and multi-sensoriality. The just-invented technologies of *Math Moves!* also prioritize multi-party collaborative action and open-ended exploration while de-emphasizing symbolic and numeric representation, further serving to disrupt the familiar tools, representations, social organization, and task structures of standard school mathematics.

In addition to the staged disruption of typical school mathematics embedded in the design of *Math Moves!*, school field trips in general are regarded by many as among the most disruptive of educational interventions. Museum professionals and floor facilitators frequently worry that school-group students wildly run “amok” (Parsons & Muhs, 1994, p. 57) as they dart chaotically from exhibit to exhibit. Teachers grapple to smooth over the ruptures field trips cause in the structure of school time while school administrators go to great lengths to address issues of liability related to taking students off campus. Meanwhile, parents rearrange schedules to drop off and retrieve their kids at unusual hours, or to accompany the trip as chaperones. And, although field trip curricula vary widely, students embarking on school excursions to museums and science centers can often expect a day characterized by non-routine activities, less stringent adult supervision, and either different forms of evaluation or the absence of formal assessment altogether. As Nespor (2000) summarizes, “field trips are disruptions in the standard grammar of school practice” (p. 29).

This video-based field study of school field trips to *Math Moves!* complements in-depth analyses of recorded episodes of situated social interaction with a broader ethnographic engagement with the communities under study (vom Lehn, Heath, & Hindmarsh, 2002). Data collection and analysis focus on naturalistic video records of student and teacher behavior in the museum and surrounding classroom activities, and are supplemented with ethnographic techniques of participant observation and informal interviewing.

Project data derive from four classroom field trips to an installation of *Math Moves!* at the Science Museum of Minnesota. Data include extensive video and audio recordings of student and teacher activity in the museum and during surrounding classroom activities, the collection of physical and digital artifacts, contemporaneous and retrospective field notes, and ethnographic interviews with teachers and students. Research participants include two classroom teachers, approximately 80 pre-algebra students from both private and public schools, and 8 parent chaperones. Students represent a range of grade (5<sup>th</sup> through 7<sup>th</sup>) and achievement levels, including both gifted students and students identified as having special needs.



**Figure 2.** A teacher and her students making “real-world connections” with an exhibit called Comparing Frequencies.

Ongoing qualitative analyses of the data in this study resist the common characterization of school field trips as bounded educational interventions that amount to isolated disruptions to the normal school day. Instead, close attention to the activity of students, teachers, and parent chaperones, both on the floor of the museum and in the classroom, reveals several ways in which the seemingly ephemeral experiences at the exhibit face are made to ramify through and entangle with life in school, home, and elsewhere. First, while on the floor of *Math Moves!*, teachers, parents, and students engage in significant interactional work to bring distal scenes, events, and vocabularies from school and everyday life into relation with present events in the museum. These interactions range from relatively explicit and targeted conversations tying specific exhibit features to elements of remembered classroom events, the “real world” (Figure 2), and generic histories of growing and development, on the one hand, to more fleeting and subtle references to pop-culture or participation in

extracurricular activities, on the other hand. Second, both on the museum floor and during surrounding classroom preparation and follow-up activities, teachers and students work to temporally situate experiences in *Math Moves!* into longer trajectories of school mathematics and science curriculum. This includes relatively brief conversations that allude to past or future topics or problems in school math and science as well as, in the case of one of the participating schools, more in-depth rearrangement of curricular schedules in order to embed the field trip in a related school mathematics unit. Finally, analyses of data from one of the participating schools reveals how elements of the embodied pedagogical philosophy undergirding the design of *Math Moves!* subtly infiltrated into the ways in which teachers and students engaged in school mathematics during the days surrounding the trip (Figure 3).



**Figure 3.** Classroom preparation activity (in the same class as Figure 1) that imported the explicit focus on whole-body motion and multi-party collaboration in *Math Moves!* into the space of the classroom.

Ongoing analyses also explore how felt contrasts between school and museum mathematics provided occasions for teachers and students to confront and assess different models for what it means to learn and do mathematics. Sometimes teachers and students navigated these differences by positioning the mathematical practices implicated in the design of *Math Moves!* as more fun and memorable routes to the same disciplinary content taught in school. At other times, students mobilized schooled models of mathematical activity in order to openly question whether *Math Moves!* should count as mathematics at all. Similar to the challenges Ma (2014, this symposium) confronted in working to disrupt classroom practice through WSG while still rendering the mathematics recognizable, the ambivalent dynamics with which participants in this study varyingly did and did not regard their own activities with *Math Moves!* as genuinely mathematical raise important questions about the relationship between the disruptive agendas of museum mathematics exhibitions and the goal of engaging learners in activities they are able to acknowledge and value as mathematics.

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# Differing Notions of Responsive Teaching across Mathematics and Science: Does the Discipline Matter?

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**Abstract:** Research in science and mathematics education suggests that the pedagogical practice of responsive teaching—teaching that notices, attends and responds to the substance (not merely the correctness) of students’ thinking—supports student engagement in disciplinary practices. However, researchers in science education and researchers in mathematics education have tended to conceptualize “teacher responsiveness” differently. This structured poster session brings together researchers of teacher responsiveness in mathematics and science to begin hashing out, with each other and with attendees, the reasons for these differences. Do the different notions of responsiveness stem from epistemological differences between mathematics and science? From differences in the knowledge bases about student thinking in science vs. mathematics? This session will frame and initiate ongoing discussions of these issues, which are central to work on teacher cognition and practices in the context of teacher professional development—the focus of a growing number of learning scientists.

## Overview: Focus of the symposium

Science and mathematics education researchers agree that effective instruction involves noticing, attending to, and responding to students’ ideas (NCTM, 2000; NRC, 2012). So, researchers have studied teacher noticing, attention, and responsiveness in classroom and professional development settings (e.g., Ainley & Luntley, 2007; Ball, 1993; Brodie, 2011; Carpenter, Fennema, Peterson, Chiang, & Loef, 1989; Carpenter, Fennema, Franke, Levi, & Empson, 2000; Coffey, Hammer, Levin, & Grant, 2011; Crespo, 2000; Davis, 1997; Empson & Jacobs, 2008; Fennema et al., 1996; Franke, Carpenter, Fennema, Ansell, & Behrend, 1998; Franke, Carpenter, Levi, & Fennema, 2001; Gallas, 1995; Hammer, 1997; Hammer, Goldberg, & Fargason, 2012; Hammer & Schifter, 2001; Jacobs, Lamb, & Philipp, 2010; Kazemi & Franke, 2004; Lampert et al., 2013; Lau, 2010; Levin, 2008; Levin, Hammer, & Coffey, 2009; Levin & Richards, 2011; Lineback, 2012; Luna, 2013; Maskiewicz & Winters, 2012; Pierson, 2008; Richards, 2013; Rosebery & Puttick, 1998; Rosebery & Warren, 1998; Russ & Luna, 2013; Schifter, 2011; Sherin & Han, 2004; Sherin, Jacobs, & Philipp, 2011; Sherin & van Es, 2009; Star & Strickland, 2008; van Es & Sherin, 2008, 2010; van Zee & Minstrell, 1997; Walkoe, 2013; Windschitl, Thompson, Braaten, & Stroupe, 2012). However, explicit and tacit disagreements about what counts as noticing or responsiveness have arisen in the literature (e.g., Carpenter et al., 1989; Hammer, Goldberg, & Fargason, 2012; Pierson, 2008; Sherin, Jacobs, & Philipp, 2011; Sherin & Star, 2011). At first glance, some of the differences seem to fall along disciplinary lines, mathematics vs. science. Our session explores questions arising from this apparent divide: Is there a real split between mathematics and science education researchers about what responsiveness looks like and what counts as “progress” toward greater responsiveness? If so, from where does it stem, and why does it matter? Should the discipline matter in defining and assessing responsive teaching, or are discipline-independent conceptions more productive for guiding research and professional development? By gathering researchers of responsive teaching in both mathematics and science in the same room to discuss these issues, we hope to help different researchers understand each other’s perspectives and clarify points of agreement, disagreement, and continuing discussion. Only through this type of dialogue among the perspectives can we develop robust characterizations of the practice of responsive teaching and subsequently use those characterizations to guide our research and our work with teachers.

Specifically, this session will feature six posters on teacher noticing and responsiveness, representing a range of institutions and perspectives. Five posters will focus on data from both pre-service and practicing teachers, gathered from both professional development and from classroom settings. **Session chair Andrew Elby** will take 5 minutes at the beginning to introduce the purpose of the session (as described above) and to quickly introduce those five posters and their presenters. (The slides from this introductory talk will constitute

the sixth poster in the session.) Then, for the next 50 minutes, attendees will visit the posters to engage in discussion with the presenters and with each other. Finally, during the last 35 minutes, **discussant Beth van Es** will synthesize the posters, offer her own perspectives from working in both mathematics and science teacher PD, and lead a discussion about the central issues of this session.

This session is of interest to learning scientists for several reasons. Given the proliferating approaches to teacher education and professional development that incorporate some notion of responsive teaching (ambitious teaching, high-leverage practices, etc.), it is essential that researchers either reach consensus about the nature of this construct or else understand the differences among various versions of the construct, and the advantages and disadvantages of those different versions for guiding research and professional development. That way, researchers can more effectively build on each other's work. With separate volumes published or soon-to-be-published on responsive teaching in mathematics (Sherin, Jacobs, and Philipp, 2011) and science (Hammer, Robertson, and Scherr, forthcoming), the time is ripe for bringing mathematics and science educators together to continue hashing out these issues.

## Major issues addressed

In this section, we first present a brief overview of the major issues spanned by the five posters. Then, we present extended abstracts of the five posters.

The major issues addressed in this symposium include the following:

- *What does responsive teaching look like?* Work in mathematics and science education that explores teacher attention often takes a unidimensional perspective; it focuses on defining to what extent a teacher's practice is or isn't responsive to student ideas. The posters in this session push to flesh out the notion of responsiveness by exploring whether and how contextual features change what constitutes responsiveness. Walkoe and Sherin's poster explores how the specific domain (or subdiscipline) of teaching influences what counts as teacher responsiveness; they document changes in noticing that arise out of participation in a video club focused specifically on *algebraic* (as opposed to general mathematical) thinking. In contrast, Luna explores how responsiveness looks different depending on whether the teacher framed the classroom activity as sharing information or making sense of ideas. Finally, Coffey and Edwards document that pre-service elementary school teachers displayed different types of responsiveness when teaching mathematics vs. science. A thread connecting these posters is the role of context in defining and explaining teachers' responsiveness. The symposium seeks to shift the focus away from the unidimensional and toward multi-faceted characterizations of responsiveness situated in the particulars of context (whether it be disciplinary domains, types of classroom activities, or school subjects).
- *What does progress toward responsiveness look like?* We are interested in characterizing responsive teaching so that we can come to understand both (1) how teachers come to practice responsiveness and (2) how we can support teachers in enacting that practice. So, a second theme of the symposium is the exploration of what constitutes progress, or productive change, in responsiveness. This focus flows out of the first: the field has to date taken progress toward "greater teacher responsiveness" to be greater attention and responsiveness to the detailed substance of students' reasoning. Such a definition of progress is a necessary side effect of unidimensional descriptions of what constitutes responsiveness. These posters suggest, however, that as our images of responsiveness become more complex and nuanced, so can our conceptualizations of progress. Building on prior work (e.g., Jacobs, Franke, Carpenter, Levi, & Battey, 2007), Walkoe and Sherin's poster described above shows that, at a fine-grained level, "greater responsiveness" might look different in different areas of mathematics (e.g., geometry vs. algebra). Richards, Gupta, and Elby, analyzing video of the same science lesson taught by the same science teacher in two different years, argue that progress toward greater responsiveness can consist not just of greater attention to substance, but rather, greater attention to certain discipline-specific facets of the substance of student reasoning. Stepping back from particular cases of progress, Russ et al. argue that what constitutes progress in responsiveness is driven by teacher and researcher assumptions about student cognition and the state of education research. Specifically, they argue that an educator's sense of what constitutes "good" vs. "less good" responsiveness depends on the extent to which the educator (i) assumes student learning consists of moving through a hierarchy of progressively more sophisticated ideas, and (ii) understands education research as having fully mapped the terrain of student thinking about that topic.

Together these two issues add complexity to our understanding of the practice of responsive teaching. The addition of that complexity provides us with a range of theoretical and empirical machinery to explore the question of the disciplinarity of responsiveness. In other words, when taken together, these posters allow us to address the question, *Should conceptualizations of responsive teaching be (sub)discipline-dependent?* Our

sense from these posters is that, in some ways, disciplinary divides may actually obscure the very complexity and substance of issues surrounding responsive teaching, issues that warrant deeper examination.

Given this overview of the most important issues addressed by our session, we now present the five posters.

## **Characterizing a New Form of Productive Change in Teacher Responsiveness**

Jennifer Richards, Andrew Elby, and Ayush Gupta

A growing body of work examines how teachers' attention and responsiveness to student thinking changes over time. This work considers the specificity with which teachers attend to students' ideas (e.g., van Es, 2011), the stance teachers take toward students' ideas (e.g., Crespo, 2000), and/or the types of follow-up moves teachers make (e.g., Pierson, 2008). While these foci foreground how teachers treat students' ideas, they do not clearly address how teachers link students' ideas to disciplinary ideas and practices. Our aim is to bring discipline-specific considerations into the discussion of changes in teachers' responsiveness.

Our perspective aligns with work emphasizing the "twin imperatives of responsiveness and responsibility" (Ball, 1993, p. 374) – grounding instruction in students' ideas while helping them learn important disciplinary ideas and practices. By looking for the beginnings of science in what students are saying and doing (Hammer & van Zee, 2006), teachers can help students see their contributions as productive in the doing of science and can help students refine their scientific thinking and content understandings.

We report on a comparative case study of two class discussions from Mr. S's seventh-grade science class. These discussions feature the same experienced teacher teaching the "same" lesson in consecutive years, attending and responding to students' ideas about the same physical scenario. We drew on a range of discursive markers to characterize his responsiveness in each case – how he revoiced students' ideas (e.g., O'Connor & Michaels, 1993), how and when he pressed on students' ideas (e.g., Brodie, 2011), and when he made bids to close the conversation (e.g., Schegloff & Sacks, 1999). We also examined video of teacher meetings and one-on-one interviews to probe Mr. S's perspective on these classroom discussions.

In the year 1 discussion, Mr. S foregrounded students' identification of the causal *factors*, the entities responsible for the motion they predicted. In general, if the factor causing the motion was not apparent in a student's explanation, Mr. S pressed the student to articulate it; if the factor was apparent, Mr. S accepted the student's response. In contrast, in the year 2 discussion, Mr. S foregrounded students' articulation of causal *stories*—mechanistic explanations—of what they thought would happen. This foregrounding involved his continued pursuit of different stories and details that fleshed out *how* the factors students identified resulted in the posited outcomes. Our poster will also examine influences on Mr. S's responsiveness in each case.

This work adds a disciplinary lens to the ongoing discussion of change in teachers' attention and responsiveness to students' ideas. Doing so raises important questions about what should count as—and where we might look for—progress in teachers' changing practices over time, and whether discipline-independent notions of responsive teaching are sufficient to capture a teacher's progress toward greater responsiveness.

## **The Subdiscipline Matters: Teacher Noticing of Student Algebraic Thinking**

Janet Walkoe and Miriam Sherin

The work on teacher noticing in mathematics primarily looks at teacher noticing of students' mathematical thinking in general without focusing on particular mathematical domains. However, exploring teacher noticing in specific domains may be important: paying attention to specific content areas can matter in professional development (e.g., Garet, Porter, & Desimone, 2001; Kennedy, 1998), and PD programs that are specific to the content teachers teach have more positive outcomes in terms of student achievement and student conceptual understanding (e.g., Kennedy, 1998). Therefore, exploring teachers' attention and responses to students' thinking in a specific content domain is likely to inform PD efforts to support the teaching and learning of that domain.

Following Schoenfeld (1988, 1998), we take the perspective that teachers' beliefs about what counts as knowing the discipline and about what students need to know to succeed influences what they attend to respond to in the moment. In the algebra classroom, attending to productive student thinking can be difficult for reasons that may be particular to algebra. Historically, algebra instruction focuses on symbol manipulation and procedures, often at the expense of a more conceptual understanding (e.g. Chazan, 1996, 2000; Kieran, 1992). As a result, many students end up manipulating symbols by rote (Kieran, 1992). We believe teacher attention may play an important role: many teachers tend to focus on symbol manipulation above more conceptual forms of algebraic thinking (Stephens, 2008; Walkoe, 2010). If teachers believe algebraic thinking is synonymous with manipulating symbols and carrying out procedures, they may fail to attend to aspects of students' reasoning that could serve as a foundation for helping students understand the content on a more conceptual level. In this poster, we describe a study that addresses this issue head-on.

Thirteen pre-service mathematics teachers in a large Midwestern city participated in the study. All thirteen teachers were asked to complete a pre and post task as well as six weekly tagging assignments using an online tagging tool that prompted teachers to watch a video and tag and discuss compelling moments of students' algebraic thinking. However, seven of the thirteen were asked to participate in a video club that focused on algebra classes.

We analyzed what moments the teachers tagged and what they wrote about those moments. Bottom-up categorization of the teachers' tagged commentaries, followed by quantitative analysis of changes in depth of various types of categories, enabled us to explore differences in noticing of algebraic thinking among members of the video club group and non-video club group.

Compared to the non-video club group, the video club group showed more change over time in the type of algebraic thinking they noticed and the depth with which they discussed student thinking. In addition, certain types of student algebraic thinking (e.g., reasoning about representations) appeared to prompt more in-depth analysis by the teachers than did other types (e.g., symbol manipulation).

This study illustrates that researchers and teacher educators can gain insights into improving PD by attending to sub-disciplinary aspects of students' thinking, such as algebra-specific types of symbol manipulations and use of representations. It also illustrates that conceptualizations of teacher responsiveness may need to be subdiscipline dependent, in focusing on the particular "distractors"—such as algebra students' rote manipulation of symbols—that tend to compete with attention to the substance of student thinking in the subdiscipline.

## **Framing the Task: Variation in One Teacher's Attention to Students' Ideas Expressed While Engaged in Disciplinary Practices**

Melissa J. Luna

This study focuses on an elementary teacher's noticing and responding to his students' ideas as they engage in science disciplinary practices. I show that what the teacher counts as "noticing student ideas" can vary according to the type of activity in which the students are engaged.

What teachers notice in student thinking, and even what counts as noticing student thinking, is context-dependent and particularly sensitive to the teacher's epistemological framing of the activity—his sense of what counts as knowledge and learning in a given moment. Thus, two bodies of prior research inform this work: (1) teacher noticing (Sherin, Jacobs, & Philipp, 2011) and, (2) teacher epistemological framing (Levin, Hammer, & Coffey, 2009). Specifically, this work examines a teacher's epistemological framing of the very specific activity of noticing students' science ideas.

To accomplish this, I equipped the teacher with a wearable camera that continuously records what the teacher is seeing and hearing; but it only saves the 60 seconds of footage that occurred immediately *before* the teacher pushes a button. The camera can save several hours of these 60-second snippets, thereby capturing events the teacher noticed immediately after the fact.

The teacher wore this camera on thirteen occasions while teaching and was instructed to "capture students' science ideas." After each lesson, I reviewed each captured moment with the teacher to clarify the student's idea and why it was chosen. Data consist of 411 video clips each with a corresponding reflection. The analysis presented in this paper uses a similar analytical approach to Russ & Luna (2013), using bottom-up coding to classify different types of captured moments, to identify patterns in those moments, and to infer from these patterns the different frames the teacher draws on when attending to students' ideas.

Across the 13 tapings, the teacher captures many different kinds of moments, from students sharing examples, to guessing outcomes, to describing instances. However, he captures three specific kinds of moments more often than others: (1) factual statements offered by students while telling information, (2) descriptions offered by students while constructing meaning, and (3) explanations offered by students while drawing conclusions. Category (1) "captures" occurred primarily during classroom activities the teacher identified as information sharing; category (2) captures primarily occurred during activities the teacher identified as sense-making; and category (3) captures occurred when the activity was drawing conclusions. This paper discusses his noticing patterns and the connection to disciplinary practices in more detail.

This research contributes to our understanding of how teachers frame the nature of "responsiveness," especially the noticing of student ideas. Responding to students' science ideas involves more than the presence of ideas and the ability to notice those ideas. It also involves a teacher's in-the-moment understanding of what counts as note-worthy ideas. This study shows that a teacher's sense of note-worthy ideas depends on the disciplinary practices in which he perceives the students to be engaged, motivating future research to investigate this connection in more detail.

## The Subject Matters for Teachers' Perceptions of Responsive Teaching

Janet E. Coffey and Ann R. Edwards

This paper argues that the subject matters for what teachers consider to be responsible, responsive teaching. Analysis focuses on establishing patterns of responsive teaching in science and mathematics, and understanding how the discipline influences how teachers respond to student ideas and reasoning. We argue that understanding these dynamics is important for teacher educators working with elementary teachers, who generally teach across disciplines and who often do not have strong backgrounds in mathematics or science.

We situate this work within efforts to establish more empirically-grounded and practice-based accounts of pedagogical content knowledge (Ball & Bass 2003; Kazemi et al, 2009; Putman & Borko, 2000). We align with work that seeks to better understand and support teachers' learning of "high leverage" practices within disciplinary areas (Franke & Chan, 2006). We consider the ways in which content knowledge and backgrounds become consequential as teachers interact with students in different disciplines.

Primary data come from a semester-long course within a STEM certificate program for practicing elementary teachers. Data include (i) video records of course meetings and (ii) course assignments such as written reflections and activities involving analyses of students' scientific and mathematical thinking, field-based assignments involving instructional design and implementation, observations of teaching, and written assignments probing the teachers' own mathematical and scientific thinking.

Analyses sought to examine the nature of differences and similarities across subject areas. Iterative coding yielded categories and revealed patterns of variation. Several cases were chosen for closer analysis that either represented typical patterns or that contrasted to prevailing patterns. Categories were then used to structure a closer comparative analysis of parallel assignments and participation in course activities for selected cases.

We build on a previous study of mathematics and science methods pre-service coursework that revealed that the same prospective teachers often attended differently to student thinking and participation across subjects, due to their orientation towards and relationship with the disciplines of mathematics and science (Coffey & Edwards, in revision). This paper focuses on data from a professional development setting. Contrasts in what participants noticed in videos of math and science teaching suggest the extent to which school standards and school curricula shape teachers' ideas of the nature of the discipline, constraining their sense of what counts as "responsiveness." The teachers in the professional development course responded critically to interactions in Deborah Ball's classroom (the "Sean's numbers" video) where an elementary classroom argued about whether 5 was an even or odd number. They were critical of Ball's choice to encourage the argument, particularly when one boy, Sean, took the position that 5 was both an even and odd number. They were unanimously concerned that Sean's idea was incorrect and that allowing the idea to persist would undermine students' understanding of even and odd. By contrast, the same group of teachers had a very different reaction to a video of students at the same grade level discussing whether air is matter or not matter. When in the video a student offered that air could be both matter and not matter and the student's teacher encouraged other students to respond to this idea, teachers in the professional development expressed excitement about the nature of the student reasoning and were supportive of the teacher's moves facilitating the discussion. The parallel nature of the examples and differing reactions highlight how teachers' perceptions of math and science as school subjects, in addition to as disciplines, shape their responsiveness.

This work contributes to teacher education literature that shifts the focus of pedagogical content knowledge from requisite teacher knowledge to practices through which that knowledge is employed, importantly in interaction with and in response to students' ideas and reasoning (Kazemi et al, 2009). We highlight the capacity of teacher education and professional development to help teachers establish practices of disciplinary attending that contribute to more robust notions of disciplinary learning and understanding and deeper conceptual understandings - for teachers and their students. We argue for the importance of supporting teachers' navigation across subject areas - including across the nature of the discipline and the disciplines as represented in school and text. We also intend this work to inform the debate on the discipline-specificity of "teacher responsiveness" by illustrating how variations in teacher responsiveness across school subjects might not align with variations in experts' responsiveness across different authentic disciplinary practices.

## Is the Discipline Really the Issue? Why Mathematics and Science Educators Sometimes Disagree about What Counts as "Responsiveness"

Rosemary Russ, Andrew Elby, Jennifer Richards, Janet Walkoe, Amy Robertson, and Melissa J. Luna

A variety of professional development (PD) has been designed to support teachers in enacting the practices of responsive teaching (e.g. Fennema et al., 1996; Hammer & van Zee, 2006; Sherin, Jacobs, & Philipp, 2011; Windschitl, Thompson, & Braaten, 2011). Examination of these PD efforts reveals differences in how PD designers conceptualize responsive teaching and its development in teachers. In this work we propose a

framework for characterizing and helping to explain the differences in the (sometimes tacit) conceptualizations of responsive teaching evident in these diverse research and professional development efforts. We suggest that this framework allows us to see through seemingly disciplinary differences among professional development efforts to the assumptions that underlie those efforts.

Our framework arises out of the perspective that an educator's conceptualization of responsive teaching reflects her (tacit or explicit) views about (i) the nature of student learning, and (ii) the ways in which research about students' learning of a given domain can and should inform teaching in that domain. Therefore, articulating researchers' tacit or explicit understandings of student cognition (e.g. Hammer, 1996) and their views about the role of research in teaching is essential for making sense of differing conceptualizations of responsive teaching.

To explore conceptualizations of responsive teaching, we conducted secondary analyses of published work on professional development (PD) and research targeting responsive teaching. We looked for patterns connecting the conceptualization of responsive teaching enacted in the PD or operationalized in the research, the researchers' assumptions about students' cognition and learning, and their views about the role of research in PD and teaching.

We argue that the differences between conceptualizations of responsive teaching can be characterized and explained largely by the educators' views about the extent to which (1) education research has fully mapped the terrain of student thinking in that domain, and (2) student learning in a given domain consists of moving through a hierarchy of progressively more sophisticated stages of thinking.

Some of the work on responsive teaching in mathematics (tacitly or explicitly) assumes what we call a Covering Model, according to which student thinking has been mapped in sufficient detail to specify a hierarchy of ways of thinking through which students typically progress. A paradigmatic example of a Covering Model drives PD in *Cognitively Guided Instruction* (CGI) (Fennema et al., 1996; Franke et al., 2001). CGI PD builds on the extensive, fine-grained body of research about early elementary students' thinking in arithmetic. The PD teaches teachers about the common stages of reasoning (set of strategies) students use and how to help students build on their current strategies to reach the next stage. So, CGI and other Covering Model-based PD assumes that the terrain of students thinking in the domain is quite well mapped and that student learning—with proper instructional support—generally progresses through predictable stages. Therefore, expert responsive teaching in the CGI paradigm consists largely of (a) recognizing which previously-documented strategies a student is using and (b) choosing problems and instructional moves designed to help students reach the next level of thinking—though of course, teachers should be ready to “hear,” interpret, and improvisationally respond to unexpected reasoning.

By contrast, PD in the *Learning Progressions in Scientific Inquiry* project (Hammer, Goldberg, & Fargason, 2012) proceeds from the assumptions that (i) there is substantial variability and unpredictability about how students will reason about a given scenario relating to a topic such as energy, and (ii) learning is highly individualized, involving a complex interplay of evolving conceptual understandings, habits of mind, epistemic stances, and emotions. Therefore, PD in this project focuses largely on helping teachers to interpret the substance of student reasoning and to improvise next steps in response to various facets of that thinking (conceptual, epistemic, etc.). In this paradigm, expert responsive teaching consists largely of “hearing” and improvisationally nurturing the seeds of productive conceptual understandings and scientific practices in the substance of students' reasoning—though of course teachers should draw on research and their own experiences to recognize and plan for common patterns of reasoning.

To be clear, we do not think either of these two models of PD is “better” than the other, nor do we make claims about the validity of the assumptions underlying either model. Additionally, our short summaries of these models likely overemphasizes the differences between them, differences we view more as points on a continuum than as a dichotomy. Our purposes in doing so are to demonstrate and explicate how:

1. Differences in conceptualizations of good responsive teaching, and corresponding differences in PD regimens and assessment tools, stem in part from researchers' different assumptions about (a) how well-mapped student reasoning is in the targeted domain (b) the degree to which student learning can be characterized as progress through progressively more sophisticated stages of thinking.
2. In mathematics and science education, some of the seemingly intra- and inter-disciplinary differences in conceptualizations of responsive teaching stem from point (1) instead of from actual differences in (sub)disciplinary epistemologies.

## Potential Significance of the Contributions

Historically, work in the learning sciences has focused more on student cognition and on learning environments than it has on teacher cognition and teacher interactions with students. This is starting to change, with a growing number of learning scientists doing research on teacher thinking and practices. A focal point for much of this research has been the construct—or really, a cluster of related constructs—of teacher

noticing/attention/responsiveness, with work done by the contributors to this symposium and by others. What has been missing is sustained cross-talk between work on science teacher responsiveness and work on mathematics teacher responsiveness. In our view, the major contribution of this symposium is bringing together LS-oriented researchers of teacher responsiveness, including both participants and attendees, to begin discussions and (we hope) collaborations that will continue for years.

Of course, simply bringing people together isn't enough. In section B above, while describing the individual posters and also the broader themes cutting across the posters, we made the case that this symposium pushes the field forward by helping to frame and initiate discussions about cutting-edge, contested central issues in conceptualizing, operationally defining, and assessing teacher noticing/attention/responsiveness. In doing so, we hope to refine and accelerate the contributions of LS-oriented researchers to understanding teacher cognition and practice. A deeper understanding of teacher cognition and practice in general, and teacher noticing/attention/responsiveness in particular, can contribute not only to theory-building about cognition and interaction, but also to teacher education and professional development efforts aimed at helping teachers foster deeper conceptual learning and productive disciplinary engagement (Engle & Conant, 2002) in their students.

## How the presentations fit together

As just discussed, the point of this session is to bring together—and we hope, enlarge—the LS subcommunity focused on teacher responsiveness, in order to frame and initiate discussion and collaboration among researchers focused on mathematics teachers and those focused on science teachers.

The posters form a coherent whole. As discussed at the beginning of Section B, the posters individually and collectively address the following cluster of tightly related issues:

- *What does responsive teaching look like* in light of contextual factors such as those leading the teacher to frame of the classroom activity in particular ways, the teacher's views about and experiences with the subject being taught, and competing foci of attention associated with particular (sub)disciplines (e.g., students' rote symbolic manipulation in algebra)?
- *What does progress toward responsiveness look like* in light of (sub)discipline-specific foci of attention associated with productive disciplinary engagement and the researcher's assumptions about the nature of "good teaching" based on their reading of the research on student learning?
- *Should conceptualizations of responsive teaching be (sub)discipline-dependent*, and if so, in what ways? The answer, of course, is bound up with the first and second issue.

In brief, the posters all address the contested issue of how best to conceptualize "teacher responsiveness," and the Session Chair's introduction will focus on highlighting that coherence.

## Relevance to conference theme

We end with a brief speculation about how research that builds on this session might relate to the conference theme. Conversations among the contributors to this symposium have revealed a shared experience in working with teachers who became significantly more responsive: Becoming "more responsive" in various technical senses was bound up with the teachers' changing visions of themselves as teachers, and with their "professional vision" (Sherin, 2001). Yet, this notion of becoming a certain kind of teacher has received minimal attention in the teacher noticing/attention/responsiveness literature. We acknowledge that our own work has generally backgrounded issues of identity and becoming. Interestingly, however, work in progress by some of the participants has begun to foreground these issues.

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# Making the Most Out of It: Maximizing Learners' Benefits from Expert, Peer and Automated Feedback across Domains

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**Abstract:** Across a variety of domains, formative feedback is often regarded as beneficial, if not crucial to learning. Yet studies show that this assumption does not always hold true: some types of feedback do not benefit learners. This symposium brings together researchers investigating how feedback can be optimized to maximize potential benefits. The four papers include studies investigating the effectiveness of feedback from various sources including expert, peer and automatically generated feedback in the domains of writing and math. The studies use a variety of methodological approaches including behavioral studies, eye tracking, and data mining. The discussion emanating from the results to be reported during the symposium will focus on how these empirical findings can help to inform feedback delivery in the classroom and how to more effectively design automated feedback.

## Symposium Description

Across a variety of domains, formative feedback is assumed to enhance learning. Yet learners often have difficulties capitalizing on feedback. A critical educational issue and a core challenge involve finding ways for students to more effectively benefit from feedback such that feedback helps students to improve performance and learning outcomes. This interdisciplinary symposium brings together research on feedback effectiveness from a variety of perspectives that examine various qualities and sources of feedback including peer, expert and automated feedback. We focus on (1) understanding students' challenges in benefiting from feedback, and (2) provide recommendations for optimizing conditions to maximize potential benefits.

Formative feedback refers to information that is provided to the learner in order to change the learner's behavior for the purpose of improving learning (Shute, 2008). Formative feedback includes information on how to direct learners' attention to response errors, response quality, or misconceptions. It can be provided by various sources, such as peers, experts, or automatically generated by computer software.

The complexity of conditions and contexts points toward the need for a multidimensional perspective on feedback to better understand students' challenges in taking advantage of feedback while learning. When exploring feedback effectiveness, there are a number of factors to consider, including (a) feedback quality and source, (b) learner characteristics, and (c) instructional settings (Narciss, 2013). Depending on the feedback quality, students may respond to feedback with skepticism and are likely to reject feedback upfront (Roscoe & McNamara, 2013). Furthermore, although feedback may potentially help learners to focus their attention on errors, it can sometimes decrease opportunities to process key information (Eva et al., 2012). Immediate feedback, for instance, has shown to be effective for enhancing performance in the short term but can be detrimental for long-term retention or skill acquisition (Goodmann & Wood, 2004). Additionally, feedback can be more or less effective depending on learner characteristics (Mathan & Koedinger, 2002). Indeed, one factor that may contribute to the inconsistency of findings across studies on feedback is the wide variability in students' prior knowledge, skills, or attitudes (Narciss, et al. 2014). Other important factors to take into account are the instructional setting (Narciss, 2013), and the amount or specificity of support provided through feedback messages (e.g., Goodman, Wood & Chen, 2011).

A further issue regards the challenge of considering assessment both in terms of online process data as well as post-task learning outcomes. A better understanding of the factors that impact feedback uptake will require considering how students interpret and understand feedback. Various methodological approaches such as eye tracking and data mining enable investigations of students' responses to feedback during the learning process. In addition, automated essay scoring enables researchers to investigate factors that influence feedback uptake at a larger scale.

The four presentations included in this symposium address and discuss these issues from a variety of perspectives. The authors' findings have both theoretical and practical implications. On a theoretical level, the results improve our understanding of the factors that influence the effectiveness of formative feedback from various sources. On a practical level, the findings inform practitioners and teachers regarding techniques to optimize students' use of feedback and guidelines for designing automated feedback.

**Markus Bolzer, Jan-Willem Strijbos, and Frank Fischer** investigated the impact of competence level of the peer feedback sender and content of the peer feedback on perception and essay revision performance; they took mindful (cognitive) processing of peer feedback into account and included an eye tracking measurement.

**Astrid Wichmann, Moshe Leiba, Alexandra Funk, Nikol Rummel, and Miky Ronen** present two studies investigating feedback effectiveness, particularly feedback uptake in the domain of academic writing. In the first study, the authors explored the impact of the assessor's expertise level (peer vs. expert), while the second study focused on the impact of sense making support. In addition to feedback uptake, trust (study 1) and revision skills (study 2) were assessed.

**Olaf Peters, Susanne Narciss, and Hermann Körndle** developed and evaluated a formative assessment and feedback script to support feedback generation in the domain of vocational education. The authors were particularly interested in comparing the effects of generating feedback to a peer vs. to one's own. As part of an iterative design cycle, script effects on (a) student's perceptions of assessment activities and (b) their revision activities were investigated.

**Rod Roscoe, Laura Varner, Erica Snow, and Danielle McNamara** evaluated the implementation and effectiveness of automated formative feedback in the Writing Pal. Feedback uptake in the Writing Pal has been iteratively improved in design experiments by reducing obstacles of unhelpful, overwhelming, or threatening feedback while maintaining a focus on formative assistance. In this study, the authors examined the quality of students' original versus revised essays, using automated tools to detect patterns of revisions implemented by students.

Each of the four presentations will include discussions of the research objectives, research questions, methods, results and implications. The four presentations will be followed by a discussion with **Professor Chris Quintana** whose renowned contributions and extensive experience in computer-based scaffolding, along with his interest in design across a variety of domains make him an excellent choice for integrating the work in this symposium. The discussion will draw on the symposium contributions to provide recommendations on how to maximize benefits from feedback.

## **Effects of Peer Feedback Content and Senders' Competence on Perceptions and Mindful Cognitive Processing of Written Peer Feedback: An Eye Tracking Study**

Markus Bolzer, Jan-Willem Strijbos and Frank Fischer, Ludwig-Maximilians-Universität, Germany

In academic settings, writing and revising texts is a daily business. In many cases – increasingly so within university courses – students often receive feedback from a fellow student after producing a text (i.e., an essay). Peer feedback can be provided more frequently and more quickly than feedback given by one person, such as the instructor of the course (Falchikov & Goldfinch, 2000). However, there are important aspects to be taken into account. In peer feedback, many students are concerned about fairness and doubt their own and peers' skill to provide peer feedback (Van Gennip, Segers, & Tillema, 2009). Feedback quality strongly depends on feedback content, form, and function (Narciss, 2008). Strijbos et al. (2010) observed that perceptions of peer feedback were influenced by an interaction between feedback content and the competence level of the feedback sender, but no direct correlation was found between feedback perceptions and revision performance.

One important mechanism could be *mindful cognitive processing*, i.e. how deeply the presented peer feedback has been processed and understood. Several authors have emphasized the importance of mindful cognitive processing for feedback efficiency (Bangert-Drowns et al., 1991; Narciss, 2008; Poulos & Mahony, 2008; Gielen et al., 2010). A systematic investigation of mindful cognitive processing combined with the impact of feedback content and senders' competence level is still lacking. Based on the eye-mind-hypothesis of Just and Carpenter (1980), which states that what a person consciously looks at is also cognitively processed, eye tracking enables us to measure the exact amount of time (i.e., fixation duration) a person consciously views

written peer feedback. Eye tracking thus provides the means to investigate the reading process of the peer feedback and obtain more insight into mindful cognitive processing.

The present study investigates the impact of peer feedback content and competence level of the feedback sender on feedback perception, revision performance, and feedback recall. Furthermore, mindful cognitive processing will be investigated, as (a) the relationship between fixation duration and revision performance and (b) the relationship between fixation duration and feedback recall. We expect that more elaborated peer feedback and higher competence of the feedback sender lead to a more positive perception of the peer feedback, better revision performance, better feedback recall, and to more mindful cognitive processing. We expect a positive relationship between fixation duration, revision performance, feedback recall.

## Method

Forty-five psychology students (10 male, 35 female) participated in a laboratory study. In a  $2 \times 2$  factorial design, participants received a scenario that varied in feedback content (concise general feedback [CGF] vs. elaborated specific feedback [ESF]) and competence level of the feedback sender (high vs. low). In the beginning, the participants received information on academic writing including four writing criteria (simplicity, structure, conciseness, stimulation) followed by an essay with the task of imagining that this essay was their own product. After reading the essay, they received on-screen written peer feedback by a fictional peer together with information about the competence level of that peer. The peer feedback was either CGF or ESF, and was based on the four writing criteria. During the feedback reading phase, data about how the peer feedback was read – i.e., fixation duration – was gathered via a head-mounted eye tracker, to infer mindful cognitive processing. Data provided by the eye tracker included how much time the participants spent on reading criteria or content, together with the overall fixation duration on the peer feedback.

After reading the peer feedback, participants completed a questionnaire assessing peer feedback perceptions. The questionnaire consisted of 18 items referring to four scales with three items each: (a) fairness (Cronbach's  $\alpha = 0.90$ ), (b) usefulness ( $\alpha = 0.94$ ), (c) acceptance ( $\alpha = 0.84$ ), and (d) willingness to improve ( $\alpha = 0.84$ ), and one scale with six items: (e) affect ( $\alpha = 0.77$ ). The fairness, usefulness, and acceptance scales constitute 'Perceived Adequacy of Feedback' (PAF) ( $\alpha = 0.93$ ). During the next step, participants received the essay again and were asked to use the peer feedback to revise the essay. Each correct improvement to a correctly identified error received 1 point. A maximum of 29 errors, which were artificially inserted into the essay, could be identified by the participants. Revision performance for each participant was calculated as the total number of points divided by time needed for revision. After a 10 minute distraction phase of solving Sudoku puzzles, participants engaged in a free recall task during which they were asked to write down everything they recalled of the on-screen written peer feedback. In total there were 11 aspects to recall for CGF and 24 aspects for ESF. Each correctly recalled aspect received 1 point (maximum in CGF: 11; maximum in ESF: 24). Recall for each participant was calculated as the total number of points divided by the maximum amount of points to achieve comparability of both conditions. Mindful cognitive processing was operationalized as the correlation between fixation duration (total time focused on the on-screen peer feedback) with (a) revision performance and (b) feedback recall.

## Results

We found a significant main effect for competence level of the peer feedback sender on PAF:  $F(1, 44) = 9.25, p = .004, \eta^2 = .18$ , i.e. feedback from a high competent peer ( $M_{high} = 6.35; SD = 1.79$ ) was perceived as more adequate than feedback from a low competent peer ( $M_{low} = 4.49; SD = 2.20$ ). Furthermore, we found a significant main effect for peer feedback content on affect:  $F(1, 44) = 5.49, p = .024, \eta^2 = .12$ , i.e. ESF leads to a more positive affect ( $M_{ESF} = 5.24; SD = 1.67$ ) than CGF ( $M_{CGF} = 4.16; SD = 1.31$ ). Secondly, no significant effects were found for competence level and/ or peer feedback content on revision performance or feedback recall. Descriptives, however, showed a tendency towards better feedback recall in the CGF condition:  $M_{CGF} = 0.38 (SD = 0.26)$ ,  $M_{ESF} = 0.26 (SD = 0.16)$ ,  $d = .56$ . Thirdly, no significant effects were found for competence level and/ or peer feedback content on fixation duration. With respect to mindful cognitive processing, a significant negative correlation was found in both conditions between fixation duration and revision performance:  $r = -.51^*, p = .012$  (ESF), and  $r = -.54^*, p = .010$  (CGF), whereas fixation duration was uncorrelated to feedback recall in both conditions. Nevertheless, revision performance shows a significant positive correlation to feedback recall across conditions:  $r = .31^*, p = .040$ .

## Discussion and Outlook

The aim of this study was to obtain more insight into the perceptions and mindful cognitive processing of written peer feedback. In line with Strijbos et al. (2010), ESF was perceived as more adequate than CGF, and feedback from a more competent peer was perceived as more adequate than feedback from a less competent peer. In contrast, where Strijbos et al. found an interaction between peer feedback content and competence of the sender for affect, this study only found a main effect for peer feedback content, i.e. that ESF leads to more

positive affect. No significant effects were found for revision performance or feedback recall, although descriptives showed a tendency towards better recall in the CGF condition. There were no significant differences in fixation duration while reading the peer feedback. Counter intuitively, with respect to mindful cognitive processing, we found a significant negative correlation between fixation duration and revision performance in both conditions and no correlation between fixation duration and feedback recall. The correlation between revision performance and feedback recall was significant and positive. On the one hand, spending more time reading the peer feedback seems to inhibit mindful cognitive processing and results in low application of the peer feedback. On the other hand, participants were still able to recall some aspects of the peer feedback, which shows that at least a basic amount of mindful cognitive processing occurred. A possible conclusion is that the participants suffered from an overload. Shute (2008, p. 177) claims it is important to “provide elaborated feedback in small enough pieces so that it is not overwhelming and discarded”. Additional insights into the perceptions and mindful cognitive processing of written peer feedback could add to the efficiency of peer feedback practice in university courses.

Based on these findings, we recently completed the data collection of a follow-up study with a slightly different design: the on-screen peer feedback is presented simultaneously with the essay and contains justifications in one condition. Justifications were added to the peer feedback, as their presence appears to increase revision performance (Gielen et al., 2010). Simultaneous presentation allows for integrative transitions between essay and peer feedback, which serve as an additional measure to infer mindful cognitive processing (Mason, Pluchino, Tornatora, & Ariasi, 2013). Finally, given the possible overload observed in the initial study, a self-report measure for perceived cognitive load was included after reading the peer feedback, essay revision, and feedback recall. Results will be presented at the conference.

## **Investigating Feedback Uptake by Looking at the Assessor's Level of Expertise and Providing Sense-Making Support**

Astrid Wichmann, Alexandra Funk and Nikol Rummel, Ruhr University Bochum, Germany  
Moshe Leiba and Michaela Ronen, Holon Institute of Technology, Israel

In this paper, we report results of two studies investigating feedback effectiveness by examining students' feedback uptake in the domain of academic writing. Drafting and revising texts is a challenging task for students especially in the beginning of their academic careers (Wichmann & Rummel, 2013). Peer feedback from an assessor can help the assessee to meet the challenges of successful revision, because feedback can be provided more quickly and frequently (Falchikov & Goldfinch, 2000). However, students often exhibit poor feedback uptake and thus fail to capitalize on feedback they receive (Van der Pol, Van den Berg, Admiraal, & Simons, 2008). Feedback uptake refers to changes made to the assessee's product during revision. On the one hand, students' problems of feedback uptake might be related to available information regarding the assessors' expertise. Several studies have investigated the impact of the assessors' expertise, comparing peer feedback with teacher feedback (Leki, 1991) or comparing different levels of expertise (Strijbos, Narciss & Dünnebier, 2010). There is agreement that the level of the assessors' expertise affects assessee's perceptions of the feedback and their trust. In other words, depending on whether feedback comes from a peer or a teacher, students might trust the assessor to different degrees. Trust might then affect feedback uptake. On the other hand, problems of feedback uptake might be related to deficits in students' understanding of the feedback and lack of reflection. Writers often reject feedback upfront without engaging in sense-making processes or have problems with managing the feedback (Boero & Novarese, 2012). However, sense-making processes are crucial because understanding the problems the feedback relates to is necessary for improving performance (Nelson & Schunn, 2009). Support is needed for students to make sense of feedback with the goal to prevent feedback rejection, to increase feedback understanding, to organize and plan steps to correct detected problems, and thus to improve feedback uptake. Thus, supporting sense making should improve students' revision skills. Based on the students' problems of feedback uptake in academic writing, we conducted two studies: In Study 1, we explored the impact of the assessor's expertise level (as labeled in the feedback) on feedback uptake and on students' trust. In Study 2, we investigated the influence of sense-making support on feedback uptake and revision skills. We expected that providing assessees with sense-making support as they received feedback would improve feedback uptake and revision skills.

## **Methods**

Study 1 was conducted in an authentic setting with first year undergraduate students who were enrolled in an Academic Literacy course in Israel (52 students 21 male, 31 female). As part of the course requirements (20% of the course overall grade), students wrote a short essay according to criteria of academic writing. After having submitted their first version, each student was asked to review two of the peers' essays (presented anonymously) and to provide constructive feedback for improving these essays. This resulted in two feedback comments for each essay, which differed in quality and specificity. Next, one of the two feedback comments for each essay

was randomly labeled as "expert" or "peer". Each student received the two labeled feedback comments and was asked to revise his or her essay accordingly and to submit a final version. The study was conducted online over a period of 21 days. The CeLS environment (Ronen & Kohen-Vacs, 2010) was used for orchestrating the activity: selectively administering the essays and feedback comments and presenting the instructions and research instruments. Feedback uptake and trust were assessed as dependent variables. Feedback uptake was measured by counting the instances of text change divided by the instances of concrete comments given. Trust was assessed using a self-report questionnaire including 8 items on a 1 to 5 Likert scale. In addition, feedback specificity was measured because it differed across expertise levels. It was assessed by counting the instances of concrete comments given divided by the instances of all the comments given (specific and general).

Study 2 comprised 67 (13 male, 54 female) participants. The students were recruited from three courses of the bachelor program in educational sciences at a major German university. Students participated in the study as part of their regular course activities. The study followed an experimental design with sense-making support as independent variable. Students were randomly assigned to one of two conditions: Sense-Making Support (SMS+) condition and No-Sense-Making Support (SMS-) condition. Sense-making support aimed at encouraging the student to reflect on the feedback. Students were asked to rank and to judge received feedback and to plan their corresponding revisions. The academic writing task was conducted over a period of 10 days in which students created a draft in MS Word, received feedback from an assessor, and revised the essay. The feedback included 12 comments on errors that frequently occur. Students were informed that the feedback was given to them by a peer; however, the feedback was given by trained tutors in order to control for the amount and kind of feedback. We used Moodle (Moodle, 2013) to distribute instructions and questionnaires. Feedback uptake and revision skills (Pre-Post) were assessed as dependent variables. Feedback uptake was assessed by counting the instances in which a text change was successfully made. Revision skills were assessed using counterbalanced pretest and posttest versions. The pretests and posttests assessed two distinct skills related to academic writing: problem detection and problem correction.

## Results

Study 1 (focus on assessor's level of perceived expertise): As expected, students trusted the experts more than they trusted their peers ( $t(51) = 2.89, p < .01$ ). In general, students who trusted the feedback more also considered feedback comments to be more helpful ( $r(\text{expert}) = .39, r(\text{peer}) = .66, p < .01$ ). Students' trust of the expert was not related to the specificity of the feedback. Concerning feedback uptake, students who received and reacted to specific feedback ( $N = 40$ ) tended to correct more feedback labeled as "expert" than feedback labeled as "peer" ( $t(39) = 2.02, p < .05$ ). In general, students' feedback uptake was higher if the specificity of the feedback was higher ( $r(\text{expert}) = .45, r(\text{peer}) = .46, p < .01$ ).

Study 2 (focus on sense-making support): Unexpectedly, we did not find significant differences between the conditions SMS- and SMS+ concerning feedback uptake,  $F = 1.88, p = .18$ . In general, participants used a large amount of the feedback comments (81.43%) to make changes. Participants made successful changes with respect to 50.16% of the feedback comments. For revision skills, we did not find a significant difference between conditions concerning revision skills (problem detection skill:  $M = 41.72, SD = 16.97, F = .08, p = .78$ , problem correction skill:  $M = 72.1, SD = 15.35, F = .74, p = .39$ ).

## Conclusion

The main goal of both studies was to investigate feedback effectiveness by examining students' feedback uptake as a function of different levels of assessor's perceived expertise (peer and expert) and different levels of sense-making support. In study one, students showed higher trust towards feedback comments labeled as expert feedback. The expert is trusted due to declared authority (the expert title) while the peer is trusted according to his/her professional authority (more specific feedback comments). One reason might be that an expert is viewed as more capable of detecting problems than a peer and thus is more likely to help improve the essay. We found that students' feedback uptake was higher when the specific feedback was attributed to an expert source than when attributed to a peer. In line with research on feedback content, students' feedback uptake increased with feedback specificity (Narciss, 2013). In study two, we attempted to improve feedback uptake by providing sense-making support. We cannot be sure that our sense-making support helped students during feedback uptake or with revision skills acquisition. One reason may be that feedback was easy to take up because feedback comments were very specific and students had little problems understanding it. This might have made sense-making support redundant. In general, we found interesting results on feedback uptake and revision skills. Feedback uptake was surprisingly high, given relatively low uptake rates in other studies of peer assessment (e.g. Van der Pol et al., 2008). In the revision skills posttest, we found that students scored low on problem detection and high on problem correction. In other words, it seemed easy for students to correct errors based on feedback during the activity and during the posttest. Yet, results from the posttest indicate that students had difficulties with detecting errors.

From these studies we can conclude that feedback effectiveness depends on the way feedback is presented. Besides looking at feedback uptake (how students change text based on feedback they receive), future studies should assess how well students detect errors during writing and explore how students can be supported to better detect errors.

## **Development and Evaluation of a Formative Assessment and Feedback (FAF) Script to Support Generating Feedback to a Peer versus to One's Own Performance**

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Numerous studies have documented the benefits of giving peer feedback (e.g., Cho & Cho, 2011) and its impact on self-assessment processes (Topping, 1998). This study aims at transferring these findings to vocational education, namely apprenticeship of metal cutting mechanics. In order to carry out the cutting mechanic's job efficiently, craft skills and planning skills are required – planning the production procedures and creating the programs for Computerized Numerical Control (CNC) machines is a core task for cutting mechanics. Novices in this field often struggle with this complex task (Berner, 2009) because there can be more than one correct planning solution. Thus, it might be a powerful strategy to implement systematic peer feedback to support the acquisition of planning skills. By comparing the approach of their peers with their own planning processes, students can reflect on the strengths and weaknesses of different planning solutions. Such comparisons may improve their own subsequent planning.

Importantly, peer assessment activities do not always improve learning (Kollar & Fischer, 2010). One reason might be that, in particular for complex tasks, students have difficulties assessing their own performance, or assessing peer performance and generating useful formative feedback. Thus, they may consider the assessment activities as useless and inadequate. Following the argumentation of Falchikov (2005) and Dochy, Segers and Sluijsmans (1999), the implementation of a feedback script might support students in assessing and generating feedback. If this is the case, providing a feedback script should also have a positive effect on students' perceptions of their assessment activities, and help them to use the assessment activities for revising and improving their solution. However, these assumptions may only hold true if the feedback script provides information that is perceived as useful and necessary for the assessment or for performance improvement on the given task.

The goal of this project is to develop a formative assessment and feedback script (FAF-script) to support feedback generation. We are particularly interested in comparing the effects of generating feedback to a peer vs. to one's own performance. As part of an iterative design cycle, we investigate script effects on (a) student's perceptions of assessment activities and (b) their revision activities.

### **Method**

In a first step, we iteratively developed two versions of a feedback script in collaboration with experienced vocational teachers using insights from Gan's work on assessment scripts (Gan, 2011). The first script comprised general guidelines on how to provide the feedback. The second script offered general guidelines and specific hints regarding assessment criteria and standards for feedback generation. The acceptance of the two feedback script versions was evaluated with 21 vocational students (male, second year of apprenticeship). Results of this study revealed that the script version that included specific hints was perceived as more useful than the more general version. However, students stated that they found it difficult to keep all of the criteria in mind because the feedback script with both general guidelines and specific hints was presented on a separate sheet of paper.

Based on these findings, a tabular version of the assessment task was developed that included prompts on how to proceed for assessing a cutting-mechanic plan. Cues mentioning the specific assessment criteria script were provided on a note card (hereafter referred to as formative assessment and feedback (FAF) script. The FAF-script was evaluated with regard to feedback quality and feedback perception by the peer assessors. Moreover, we examined if there were differences in students' implementation of the FAF-script when used to assess and generate feedback to either a peer vs. their own planning approach. Furthermore, we explored (a) students' perceived usefulness of generating peer feedback with the FAF-script, (b) students' perceptions of adequacy of the feedback they have generated with the help of the FAF-script, and (c) correlations between perceived usefulness of generating feedback and features of the peer's planning approach (i.e., number of planning ideas).

### **Participants, design and procedure**

18 apprentice cutting mechanics students (1 female and 17 male students in third year of apprenticeship) participated in the evaluation study. In the first session, all subjects planned the manufacturing process of a typical work piece and produced a working plan for all relevant steps. In the second session, students were

randomly assigned to two groups (generating feedback to a peer vs. one's own working plan – peer feedback vs. internal feedback). In the peer feedback group, students were provided with the working plan of a fictitious peer that included typical errors and were asked to generate feedback on this plan. To do so they were offered the FAF-script that included assessment criteria such as the selection and order of operations, the selection of tools and the specification of technological data (e.g. cutting speed or tool adjusting). Afterwards, students had to assess and generate internal feedback on their own planning, and were asked to revise their own initial plans on the basis of what they learned in the peer feedback process. Under the internal feedback condition, students also received the FAF-script but only assessed and generated internal feedback on their own planning, and were asked to revise their own initial plans if they thought it would improve them.

### **Measures**

Students' perceptions of generating and providing peer feedback were measured by an adapted version of the *feedback perception questionnaire* (Strijbos, Narciss, & Dünnebier, 2010). The adapted items measured how students perceived the peer feedback adequacy they had generated in terms of the scales fairness (Cronbach's  $\alpha = .82$ ), usefulness (Cronbach's  $\alpha = .61$ ), and acceptance (Cronbach's  $\alpha = .67$ ). Students had to respond to these items on a 10 centimeters bi-polar scale from 0 "I fully agree" to 10 "I fully disagree". Furthermore, we assessed the perceived usefulness of giving peer feedback to improve assessors' own planning with 7 items (e.g., generating peer feedback was very helpful for revising my own plan; Cronbach's alpha .83). *Peer feedback quality* was measured (a) by the number of errors detected and (b) how it addressed the criteria of the FAF-script. *Revision performance and activities* were measured by the number of errors detected and corrected.

### **Results**

Students in the peer feedback group stated that providing feedback on a peer's working plan was helpful for revising their own planning (median = 4.0, *IQR* = 2.0). Most apprentices stated that they used the criteria offered by the feedback script to generate the peer feedback (median = 4.0, *IQR* = 1.0). On average students stated that they used these criteria to generate internal feedback and to revise their own planning, but the variance between students regarding their use of criteria was high (median = 4.0, *IQR* = 3.0). A preliminary analysis of peer assessors' internal and peer feedback quality revealed that peer assessors detected and revised most errors in the peer plan ( $M = 15.56$ ,  $SD = 5.59$ ) but rarely detected errors in their own planning ( $M = 1.89$ ,  $SD = 2.42$ ). This difference was statistically significant ( $Z = -2.67$ ,  $p = .008$ ,  $\phi = -.88$ ). The detected errors mostly related to the criteria selection and order of operations. These impressions need to be confirmed in an in-depth analysis of the individual planning and feedback quality in both groups with regard to the type of revised working steps and errors that had or had not been detected.

Peer assessors perceived that the feedback they generated based on the feedback script was useful ( $M = 1.91$ ,  $SD = 1.13$ ) and fair ( $M = 3.50$ ,  $SD = 2.53$ ), and that they would accept the given peer feedback ( $M = 2.08$ ,  $SD = 1.13$ ). A correlation analysis revealed a significant correlation between the use of planning ideas offered in the peer working plan and the perceived usefulness of providing feedback on the peer working plan to improve the assessors' own planning ( $r = .80$ ,  $p = .01$ ). Additionally a significant correlation was found between the use of the feedback script for providing peer feedback and the perceived fairness of the given peer feedback ( $r = .61$ ,  $p = .03$ ).

### **Conclusions and Outlook**

The results of the studies above indicate that the students consider it helpful to generate feedback to a peer because in doing so they realized potential improvements they could implement in their own work. The FAF-script was not perceived as a redundant burden but as a helpful guide for providing useful peer feedback. When using the FAF-script, students felt confident that their given feedback was perceived as fair, which was important for overcoming fears of being unable to provide high-quality peer feedback.

As a next step of this iterative design cycle, we initiated another study with 107 apprentices of cutting mechanics. Within this study, a quasi-experimental two-factorial design was used to investigate the influence of two factors, (a) generating feedback on a peer's plan vs. one's own plan, and (b) feedback generation with vs. without the FAF-script. Students had to accomplish a slightly different planning task. Analogous to the exploratory study, the effects of the conditions were investigated with regard to feedback quality, feedback perception, and revision performance in order to investigate the issue of what are the benefits of generating peer vs. internal feedback for a complex vocational task. The results of this study support the findings of the pilot study. Again students considered it helpful to use the FAF-script for peer- and self-revision activities. Students with the FAF-script perceived their feedback quality as significantly more fair, useful and acceptable than students without the script. Most students stated that they adopted ideas from the peer draft to revise their own plans. Results of both studies will be presented and discussed at the ICLS 2014.

# **Designing Usable Automated Formative Feedback for Intelligent Tutoring of Writing**

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## **Student Resistance to Automated Writing Feedback**

Many educators have voiced doubts about the validity of automated writing evaluation (Deane, 2013). Students have expressed similar concerns, which hinder their implementation of automated feedback when revising (Grimes & Warschauer, 2010). For example, in the Writing Pal (W-Pal) tutoring system (Roscoe & McNamara, 2013; Roscoe, Varner, Weston, Crossley, & McNamara, in press), students can write prompt-based essays and receive automated scores and feedback. Prior feasibility research revealed student doubts about the feedback system. Over 140 high school students used an early version of W-Pal in their English classes for a school year. Although students' writing improved and most students rated the system as easy to use, some students reported difficulty with reading the feedback (23.7% of students), using the feedback (24.6%), understanding the feedback (38.3%), or quantity (50.4%). Students' critiques related to specificity ("the feedback needs to be more helpful for us on our own personal essay") and usable recommendations ("W-Pal never really tells you what you need to improve on"). Such challenges are exacerbated by students' reluctance to make substantive, document-level revisions rather than surface, word-level edits (Crawford, Lloyd, & Knoth, 2008; Fitzgerald, 1987).

## **Responding to Students' Concerns about Automated Feedback**

To create software that supports writing instruction and promotes substantive revising, students' doubts about automated feedback must be allayed via careful design. Guided by research on revising and formative feedback (Fitzgerald, 1987; Shute, 2008), W-Pal feedback focuses on high-level writing goals and recommendations (e.g., elaboration of ideas); W-Pal provides no lower-level feedback on spelling, grammar, or punctuation errors. In response to student reactions to W-Pal, feedback messages were rewritten to ensure that *problem identification* statements (i.e., issues to address) were made in an impersonal and suggestive manner. Instead of stating, "Your essay *does not*" the feedback states "*This essay may not*" In contrast, recommendations for *problem resolution* (i.e., actions to improve the text) were rewritten to be personal and specific. For instance, rather than stating, "A good strategy for linking ideas" the feedback states "One way that *you can link your ideas*" Yet another change granted students more *control* over feedback quantity. All students receive one message on the most critical issue (Initial Topic). Students can then request more feedback on that Initial Topic and/or feedback on the next most serious problem (Next Topic). Such changes sought to improve feedback uptake by reducing obstacles of unhelpful, overwhelming, or threatening feedback while maintaining a focus on formative assistance.

The revised W-Pal (Roscoe et al., in press) was evaluated with a new sample of high school students. In this report, we consider (1) the quality of students' original versus revised essays and (2) the nature of students' revising. An innovative contribution of this work is that revision patterns were assessed via automated computational tools rather than time-consuming annotation by human raters.

## **Method**

High school students ( $n = 87$ ) participated in a 10-session program using W-Pal. The first and final sessions collected data on individual differences and overall writing proficiency. Students began each of eight training sessions by writing a prompt-based, persuasive essay. A different argument topic was assigned each day, in the following order: *Planning, Winning, Patience, Heroes, Perfection, Uniformity, Beliefs, and Fame*. Students were allotted 25 minutes to draft their persuasive essays and 10 minutes to revise after receiving feedback.

Essay quality was assessed using scoring algorithms that rate essays on a 6-point scale similar to the SAT exam. Linguistic features of essays were assessed via Coh-Metrix (McNamara, Graesser, McCarthy, & Cai, in press) and focused on indicators of *word-level* and *document-level* revisions. Word-level revisions tend to capture superficial edits, such as replacing short words with long words (e.g., increase *average syllables per word*). In contrast, document-level revisions may capture more substantive changes, such as improving semantic cohesion across paragraphs (e.g., increase *LSA scores among paragraphs*).

## **Results**

A 2 (draft)  $\times$  8 (prompt) repeated measures ANOVA was conducted to examine scores across original and revised drafts and across prompts. A main effect of draft indicated that students, on average, made small ( $d = .12$ ) but significant improvements when revising their essays,  $F(1,74) = 15.42, p < .001$ . Original drafts earned a mean score of 2.56 ( $SD = 1.04$ ) whereas revised drafts earned a mean score of 2.68 ( $SD = 1.03$ ). The quality of drafts also increased gradually over time,  $F(1,74) = 9.24, p = .003$ . For example, mean scores for students' final practice essay ( $M = 2.82, SD = 1.10$ ) were higher ( $d = .47$ ) than those on the first essay ( $M = 2.34, SD = .92$ ).

In what ways did students revise? Did students focus on surface word-level revisions or implement more substantive document-level revisions? Results indicate that word-level revisions were less common than document-level revisions. For a few prompts (e.g., *Planning, Uniformity*), students made several revisions that

replaced common words with less frequent words or removed first-person pronouns. However, for many essays (e.g., *Heroes*, *Perfection*, *Fame*) our automated tools detected minimal word-level revising. In contrast, students frequently implemented revisions at the document-level. For almost every topic, students added substantive content (e.g., examples), improved organization (e.g., paragraph structure), and improved essay cohesion (e.g., linking ideas across paragraphs). Such results run counter to traditional findings that students avoid revising or implement mainly superficial edits (Crawford et al., 2008; Fitzgerald, 1987).

## Conclusion and Outlook

Supporting students' use of feedback to revise in computer-based settings faces key challenges: students doubt the validity of usefulness of the feedback, and students seem to naturally resist making revisions rather than superficial edits. To address such obstacles, formative feedback in W-Pal emphasizes higher-level processes and strategies rather than lower-level concerns, which was echoed in the observed patterns of revisions. Students appeared to use W-Pal feedback to implement revisions that improved the document as a whole (e.g., developing deeper text cohesion) rather than word choice (e.g., including more rare words). In the field of automated writing evaluation, these findings suggest that formative feedback designed to be (1) strategy-oriented, (2) actionable, (3), specific, and (4) student-controlled, may be an effective means of supporting feedback uptake. In future analyses, we will examine user surveys to reveal students' specific perceptions of the updated W-Pal system, such as whether the feedback is viewed as more helpful or understandable.

Additional research is ongoing to expand the types and content of feedback offered in W-Pal and related systems. For example, the work presented here demonstrated that aspects of student revising could be captured via automated tools. Such revision patterns can be incorporated in novel feedback algorithms. That is, instead of providing feedback only on the discrete *products* of student writing (i.e., individual essay drafts), we can now begin to give automated feedback on the writing *process* (i.e., the transformation of drafts via revising).

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# Leveraging Educative Approaches to STEM Disciplinary and Instructional Practices

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**Abstract:** This symposium addresses teacher learning and agency as teachers adapt existing curriculum and instructional practices to promote student learning through Science, Technology, Engineering & Math (STEM) disciplinary practices. Each study in our symposium aims to foster student learning of STEM disciplinary practices as an overarching goal. We focus on educative curriculum models that support teachers' identity development and disciplinary expertise by cultivating their pedagogical content knowledge for disciplinary practices in concert with student learning (Davis & Krajcik, 2005; Shulman, 1986). The multiple research projects in this symposium document practices in various learning environments that: a) broaden science participation through teachers' and students' authentic interactions with disciplinary practices, b) recognize multiple epistemologies in STEM environments for all participants, c) honor teachers' expertise in adapting curriculum for their diverse contexts, supporting equitable and authentic implementation of science practices (NRC, 2011).

## Introduction

This symposium brings together threads of research related to teacher learning and agency as we focus on how teachers adapt existing curriculum and instructional practices to promote student learning through STEM disciplinary practices. Each study in our symposium aims to foster student learning of STEM disciplinary practices as the larger goal, while recognizing that teachers need to be grounded in the disciplinary practices of their content area if they are to effectively teach them. We aim to develop educative curriculum models (curriculum for students that also contains elements of instruction for educators) that situate teachers within STEM-related communities of practice to support their identity development and expertise in these fields by cultivating their pedagogical content knowledge for disciplinary practices in concert with student learning (Shulman, 1986; Kind, 2009; Davis & Krajcik, 2005).

Methodologies of these works are diverse, but their goals are similar: to bi-directionally bridge theory with practice, and further, take curricular adaptations and innovations to scale. We document practices in a variety of learning environments that allow us to investigate and make recommendations in order to: a) broaden science participation through teachers' and students' authentic interactions with disciplinary practices, b) recognize multiple epistemologies in STEM environments for all participants, c) honor teachers' expertise in developing and adapting curriculum for their particular contexts. Our work promotes collaborative expertise among teachers in STEM content areas and situates teachers within disciplinary-specific communities of practice, enabling equitable and authentic implementation of the Next Generation Science Standards (NGSS), as envisioned in the National Research Council *Framework for K-12 Science Education* (NRC, 2011).

In the coming years, as districts transition from state-based standards to the NGSS, they will be charged with adapting their existing curriculum materials and tools to meet not only the new standards, but also new practice based-approaches to scientific inquiry (NRC, 2011; Achieve, 2013). These approaches will require teachers to become familiar with the disciplinary practices of their content area, and to develop new pedagogical knowledge and skills around teaching these practices. There is widespread agreement that teacher professional development is critical for the success of standards-based reform in U.S. schools (Committee on Science and Mathematics Teacher Preparation, 2001), and that educative curriculum is a powerful tool for this type of reform (Kind, 2009).

## **Practice-Based Approaches to Teaching**

There is currently limited research on how teachers implement practice-based approaches to STEM instruction. Penuel (2009) found teachers preferred adaption over strict implementation of designed curricula. However, teacher adaptations most often build on subject matter knowledge and pedagogical content knowledge (PCK), with no instances of adaptations specifically structured around PCK for disciplinary practices (Davis & Krajcik, 2005).

Curriculum materials have the potential to support teachers in complex work such as engaging students in scientific practices (Brown, 2009). However, teachers' enactment of curriculum materials, including teachers' support for science practices, varies (e.g., McNeill, 2009) since teachers are engaged with curriculum in a participatory relationship (Remillard, 2005). Teachers' diverse experiences and backgrounds enable them to draw on the resources in curriculum materials in varied ways and adapt the resources differently for use within the contexts of their classroom (Brown, 2009, Remillard, 2005).

## **Scholarly Significance of the Symposium**

Theoretically driven by the cultural process of learning (Lave & Wenger, 1991), teacher learning within a community of practice (Grossman, 2005), and influenced by the interrelationships between educators and their curricula (Remillard, 2005), this symposium uses diverse methodologies to investigate the ways that teachers engage with scientific practices. Papers discuss engagement in STEM practices through research bridging grade levels 3-9, pre-service and experienced teachers, and formal and informal learning settings. Considered together, these papers show that teacher learning during adaptation of practice-centered instruction is highly context-dependent. This symposium offers insights regarding successful adaptation of curricula for disciplinary practices.

## **Designing Educative Curriculum to Address Controversial Issues in Science**

Elaine Klein and Veronica McGowan, University of Washington

When scientific content has the potential to be controversial in the classroom, practice-based approaches to inquiry (as advocated for by the NGSS and the *Framework*; NRC, 2011) are integral to engaging participants via multiple pathways that facilitate their deeper knowledge of concepts and theories (Bang, Warren, Rosebery, & Medin, 2012; Kelly, Carlsen, & Cunningham, 1993). Recent work in a diversity of academic disciplines has begun to question the historically dominant assumption in science education that presenting empirical evidence alone will shift learners' understanding of potentially controversial topics; in contrast, equitable science instruction will explicitly engage students about their worldviews, as a way to foster their understanding of content (Collins & Pinch, 1993; Langen, 2004; Nisbet, 2009; Saunders & Rennie, 2011; Verhey, 2005). In terms of what actually transpires in classrooms, however, recent work in this field (Berkman & Plutzer, 2011) reveals the "cautious 60%" of public high school biology teachers from across the United States that utilize strategies to avoid controversy when teaching about evolutionary concepts. With this context as a backdrop, this study investigates public high school biology teachers' attitudes and approaches to teaching about evolutionary biology, which was identified by all participants as a controversial topic within their communities. We then use these findings to propose an educative curriculum framework that advocates for surfacing multiple epistemologies and ways of knowing within the scientific community, and offer tools and strategies to help teachers adapt this framework for their particular classrooms.

## **Conceptual Framework and Study Design**

The philosophical underpinnings of the issues described above have led many science educators and researchers to consider whether the goal of science education, especially around potentially controversial issues, is to *understand* or to *believe* scientific concepts (Coborn, 1994; Smith, 2009; Southerland, Sinatra, & Matthews, 2001). There is extensive work (Evans, Legare, & Rosengren, 2010; Legare, Evans, Rosengren, & Harris, 2012; Long, 2011), however, that affirms the capability of non-exclusivist people to move beyond this simplified binary and occupy a "Both/And" position in regard to accepting evolutionary concepts and/or timescale, while also holding theistic beliefs of some kind, even within the professional sciences (Cunningham & Helms, 1998; Doolittle, 2009; Gauch, 2006). Further, the strategies of utilizing authentic scientific practices and explicit discourse on the nature of scientific knowledge have been found to improve students' conceptual understanding of natural selection and evolution (Sandoval, 2003; Sandoval & Morrison, 2003; Sandoval & Reiser, 2004). An important clarification is that these scholars do not call for actively teaching about beliefs in science classrooms, but, rather, for teachers to foreground these conversations as a mode of engagement to move students towards conceptual understanding, especially for potentially controversial issues.

This DBR study (Design Based Research Collective, 2003) is situated within a year-long, high school biology curriculum design project called Educurious. We take the sociocultural stance that learning is explicitly a cultural process (Lave & Wenger, 1991), and recognize that engaging teachers' and students' subjectivity and

varying cultural experiences as social capital, is a powerful technique to shift their own epistemological conceptions of science (Nasir & Hand, 2006; Bang & Medin, 2010). Throughout implementation of the Educurious evolutionary biology unit, we collected and compared daily agendas, teacher-created materials, and online adaptation tracking logs for each teacher to gauge the type and degree of adaptation of this course for each classroom. We conducted semi-structured interviews with each teacher to gain a deeper understanding of their past experiences teaching about evolutionary biology, and their motivations for making content-specific curriculum adaptations to the evolution unit, and used this information to guide biweekly online discussions with the teachers. We then transcribed all of these discourse interactions, and used iterative, open coding to allow for emergent themes in the data to guide coding schemes, analysis, and theory development (Creswell, 2007); we also employed critical discourse analysis (Gee, 2011) to draw meaning and patterns from teachers' interviews, talk during meetings, and written accounts.

## **Findings**

Davis & Krajcik (2005) suggest that we need to “characterize teacher practice” before we can develop effective educative curriculum models that meet teachers’ needs. In each of the teacher interviews, participants framed evolution as a controversial topic. Within their discourse, teachers posited evolution as controversial specifically because of some students’ beliefs, but responded through their practice in diverse and complex ways. Some teachers expressed their own non-exclusivist worldviews, and discussed how they revealed this to their students, in order to model that this stance is tenable.

In regards to adapting curriculum, we found that teachers had overwhelmingly positive views and experiences with curriculum adaptation, and actually preferred adaption over strict implementation of designed curricula. Teachers most often drew on subject matter knowledge and pedagogical content knowledge when adapting for their classes; however, our research suggested that teachers do not identify with the disciplinary practices of their content areas. This suggests that an educative curriculum model should develop partnerships between teachers and disciplinary experts to help them contextualize the real-world applications of the key theories in evolutionary biology and bring authentic disciplinary practices into their classrooms.

## **Implications for Engaging in Controversial Science Topics**

The goal of all standards and curricula should be to broaden scientific participation and opportunities for students from diverse backgrounds and cultures within an equitable framework (NRC, 2011; Calabrese, 2003), yet prescribed curriculum models rarely produce the same learning gains once they are scaled up and enacted across diverse settings (Taylor, 2012; Squire et al, 2002; Penuel, 2011, Coburn, 2012), and do not cater to the specific needs of individual teachers, classrooms, and students. At their foundation, scientific disciplines exist within a broader human and cultural framework, in which individuals, including scientists, hold non-exclusivist stances around controversial ideas. Surfacing this complicated reality will help teachers to leverage their own and their students’ non-exclusivist thinking within their classrooms to create personally relevant instruction for their students. This work strives to advance the essential discussion about how high school biology teachers actually teach about evolution in the complicated social ecology of their classrooms (cf. Eilam, 2009). Our educative curriculum model incorporates tools and strategies that utilize authentic scientific practices and explicit discourse on the nature of scientific enterprise and multiple epistemologies to support teachers’ development of PCK for disciplinary practices as they adapt designed evolutionary biology unit for their local classrooms (Sandoval, 2003; Sandoval & Morrison, 2003; Sandoval & Reiser, 2004; Davis & Krajcik, 2005).

## **Teacher Learning of Disciplinary Practices**

Philip Bell, Tana Peterman, Kerri Wingert, and Jeanne Chowning, University of Washington

Through an ongoing partnership of educational researchers, practitioners and STEM professionals, we investigate questions relating to shared researcher and teacher learning through collaboration around scientific practices. Our posture is responsive to practitioners’ curricular and collaborative goals and learning needs using design-based implementation methodology (Penuel, 2011; Design Based Research Collaborative, 2003). Research questions include:

- How and why do teachers shift their teaching towards practice-focused instruction?
- How do teachers share problems of practice, resources and teaching knowledge with others?
- How do the practitioners in the school leadership team collaborate with educational researchers?

## **Research Focus**

This research examines the networks and cultural pathways (Palinkas, 2009) that teachers utilize as they continue improving their practices. We will offer solutions to the persistent gap between research and practice in K-12 STEM education, consistent with ways this gap has been addressed in medicine-related fields through the developing work of “translational research” (Woolf, 2008). During the 2013-14 school year, we have

extensively documented authentic collaborations with local science teachers in grades 3-8, through which we continue to work to solve problems practitioners face in implementing disciplinary STEM practices.

### **Conceptual Framework and Study Design**

Translational research suggests that the gap problem between research and practice should not only be addressed but reframed. Implicit in the notion of adaptation is a bi-directional process of cultural exchange in which both researchers and practitioners come to understand how the knowledge products of each field can strengthen the professional activities in the other (Coburn & Stein, 2010; Palinkas et al., 2009; Penuel, et al., 2011). We have been studying an adaptation site, in which practitioners from two school districts, educational researchers, and scientists from the Institute for Systems Biology collaboratively develop and enact curricular adaptations aligned to STEM disciplinary practices.

This collaboration, orchestrated by the school districts, asks educators to engage students in disciplinary practices to support their learning of STEM. This comes in response to the new teaching and learning expectations from the recently adopted Next Generation Science Standards (NGSS; Achieve, 2013), which is based on the Framework for K-12 Science Education (NRC, 2011). The adaptation site work is focused on collaboratively adapting curriculum and developing relevant strategies and tools to support both teachers' and students' learning of STEM through engagement in the disciplinary practices, specifically focusing on the practices of engineering design and scientific explanation and argumentation. We work with teachers to develop and analyze what curriculum materials should be provided for teachers, how curriculum materials help teachers understand the disciplinary practices, and how teachers could expand the implementation of the practices throughout the curriculum at a larger scale (Davis & Krajcik, 2005; Coburn & Stein, 2010). We fully document the process consistent with design-based implementation research.

### **Sources of Data**

Through the Adaptation Site, we are gathering several types of qualitative data with teachers as they iteratively develop educational tools and knowledge in response to STEM educational improvement efforts. Data collection is in the form of video, audio, and pre- and post-year surveys on the structure and impact of individual teacher networks. Teachers will also engage in focus groups and informal conversations to inform our understanding about their learning throughout the adaptation and implementation process. Most importantly, we will observe and participate in classroom activity with teachers as they adapt, plan, and implement their instruction. Planned data analysis will include discourse analysis of student talk, teacher talk, and talk among educational professionals, network analysis of teacher cultural learning pathways, measures of teacher content knowledge, and qualitative analysis of adapted curricula. Data collection will continue through three years, beginning with the 2013-14 school year.

### **Implications**

This research illuminates the ways that a partnership between universities, school districts and local professional organizations supports the flow of research ideas to the benefit of teacher practice and professionalization. Our DBIR approach (Penuel et al., 2011, Design-Based Research Collective, 2003) will enable us to document the full process of teacher learning: from cultural exchange to professional learning to shifts in practice to strengthened STEM learning opportunities for K-12 students. Our research will result in recommendations for helping adapt curriculum to include STEM disciplinary practices at scale, with direct connection to student outcomes. This research elucidates the ways that teachers improve their own science instructional practices through their collaborations and social networks as well as the ways that they seek and create agency in response to new standards.

## **Using Educative Curriculum Materials to Support Teachers in Engaging Students to Justify Predictions**

Anna Arias, Annemarie Palincsar, and Elizabeth A. Davis, University of Michigan

As part of a larger research project looking at the use of educative curriculum materials to support elementary teachers' and students' learning of science practices integrated with science content, this research looks closely at teachers' use of educative features added to an existing kit-based science curriculum to support students in justifying their claims, an aspect of scientific argumentation. Using a qualitative, case study analysis approach (Miles, Huberman, & Saldana, 2014; Stake, 2000), we investigate how teachers interact with and adapt educative curriculum materials to provide learning opportunities for their students and consider how patterns within the student work connect to these opportunities. We ask:

- What evidence exists that the teachers drew on the educative features of the unit to support their students to justify their predictions?
- How do teachers describe drawing on the curriculum materials to support students in justifying their predictions?
- How does the students' justification of their predictions on a pre- and post-assessment connect to the teachers' enactment of the unit?

## **Research Focus**

Scientific argumentation, defined as the justification of an explanation, model, or prediction through the coordination of evidence and theory (Duschl & Osborne, 2002), does not happen often in elementary classroom, despite evidence that elementary children can engage in aspects of this disciplinary practice (e.g., Herrenkohl, Palincsar, DeWater, & Kawasaki, 1999). We hypothesize that educative curriculum materials might support the use of justification of predictions to serve as an entrée for both teachers and students to engage in science argumentation, broadening their participation in authentic practice.

While elementary students are often encouraged to make predictions in many subjects, including reading literature, typically, all predictions are welcomed and students are not held accountable to support their predictions with reasoning or evidence. However, science emphasizes providing justification for one's claim. This disparity in how "prediction" might be used in the elementary grades makes it a particularly interesting scientific practice to study in elementary classrooms. The goal of our investigation is to study how educative curriculum materials might facilitate the development of teachers' abilities to engage students in providing justification for a claim in a prediction and thus begin to move toward scientific argumentation.

## **Conceptual Framework and Study Design**

Teachers' work with curriculum is a participatory relationship in which the resources, stances, and perspectives of the teacher and the features and resources of curriculum materials interact (Remillard, 2005). Teachers adapt curriculum materials for use in their classrooms differently in part based on their diverse experiences and backgrounds (Brown, 2009, Remillard, 2005). For example, McNeill (2009) found that science teachers drew on educative curriculum materials in different ways when supporting students to engage in constructing explanations.

As part of a large quasi-experimental study looking at the effects of educative curriculum materials, this paper centers on three fourth-grade teachers (Ms. Jay, Ms. Rosser, and Mr. Decker) teaching an Electric Circuits unit over the course of three months. We enhanced an STC kit-based, inquiry-oriented unit for Electric Circuits (National Science Resources Center, 2004) with educative features intended to promote teaching, learning, and use of science practices and content (see Davis et al., in press). We designed the educative features drawing on literature and our earlier empirical work to support teachers in integrating science practices and content. Certain features foregrounded science practices, including making predictions with justification. The educative features included: (a) overviews describing the science practice, providing a rationale for teaching the practice, and gave possible teaching moves for supporting students applicable across multiple lessons, (b) targeted, *lesson-specific suggestions* for supporting students engaging in the science practice, (c) reminder boxes that were inserted into the procedure section of lessons and intended to highlight important aspects of science practices, (d) a *rubric and examples* feature for analyzing and understanding students' written predictions, and (e) narratives describing a teacher working with students on justifying prediction.

## **Findings**

Each of the teachers seemed to draw on the educative curriculum materials in their teaching, yet their enactments showed differences in the learning opportunities they provided. For example, how each of the teachers discussed what predictions are and how to justify a prediction varied significantly. Ms. Jay and Ms. Rosser's explanations were clear and drew directly from the educative curriculum materials. Both teachers defined prediction as "a forecast of future events based on data already collected," a statement provided in the educative features. Both teachers also discussed the importance of justifying one's claim. For example, Ms. Rosser discussed that "predictions require a claim about what is being predicted and justification based on reasoning or previous observations or experiences". Mr. Decker's explanation of the practice of prediction, on the other hand, was convoluted and did not reflect the ideas in the educative curriculum materials. Mr. Decker did not focus on drawing on prior knowledge or observational data to support why one might make a particular claim as described in the educative features; instead, he emphasized how the students could see if their predictions were correct through an investigation. Similar differences across classrooms appeared in the students' work. More than 90% of students in Ms. Jay's and Ms. Rosser's justified their predictions on posttest, which was an increase from the pre-test; however, fewer students justified their predictions on the posttest than on the pretest in Mr. Decker's classroom.

The three teachers also varied in their perspectives regarding using the educative features to support student engagement in prediction. In the interviews, Ms. Jay pointed to how the curriculum materials facilitated her ability to engage students in justifying predictions and encouraged her to consider more closely students' thinking across multiple subjects. She also discussed using specific educative features such as the rubric to support students' predictions. In contrast, Ms. Rosser and Mr. Decker did not often point to using specific educative features when teaching about predictions. Ms. Rosser did discuss using sentence stems to support students in constructing explanation and justifying their predictions, which was suggested by the educative features.

### **Implications for Teaching Practices of Prediction and Argumentation**

This study adds to and extends the research base by highlighting areas of strengths and challenges that might occur as teachers interact with and adapt educative curriculum materials to support elementary students in scientific prediction and argumentation. The teachers' varied integration of the disciplinary practice of justifying predictions into their instruction points to areas of teacher learning as well as challenges, adding to other research on designing educative curriculum materials for elementary science classrooms (e.g. Davis *et al.*, in press; McNeill, 2009). Ms. Jay's positive response to, and uptake of, the educative features' focus on justifying predictions suggests that such features can help elementary teachers learn more about how to engage students in complex science practices. In contrast, Mr. Decker's struggle to understand how the educative features were defining *justification* suggests that some teachers may need additional and more explicit support from educative features or extra time to adapt suggestions in the curriculum materials for use in their classrooms. These findings have implications for designing educative curriculum materials and considering how to support teachers to use and adapt these materials within their classroom. The findings also point to the need for further research on how facilitating teachers' engagement of students in justifying prediction may serve an entrée into the authentic practice of scientific argumentation in elementary classrooms and encourage a greater focus on student thinking in teaching.

## **Teacher Identity Development through an Afterschool Club: Science STARS as an Educative Learning Environment for Adaptive Science Teaching and Learning**

April Luehmann, University of Rochester

Teaching and learning experiences that foreground science culture and practices are rare in current science classrooms, especially given the intense pressures of accountability tests and teacher accountability measures (Marx & Harris, 2006). This reality is especially problematic for preservice practitioners who are just beginning to form their fundamental beliefs and build their competencies related to effective and equitable, student-centered science education. If our newest professionals have few opportunities to develop professional appreciations for, understandings of, confidence with and commitments to the fundamental principles and goals for reform-based science teaching, it is highly unlikely that school science will soon become a place for youth to participate in the culture of science and thus build positive identities with science. This study seeks to understand ways learning-to-teach in informal spaces can be structured through a practice-based curriculum to provide novice educators meaningful, ongoing and supported opportunities to marry their disciplinary expertise with youth voices in service of the development of teachers' own reform-based professional identity.

### **Research Focus**

The focus of this research examines ways in which preservice teachers took up and modified a structured, practice-focused science curriculum for urban girls in out-of-school settings called Science STARS. The core STARS curriculum outlines benchmark performance events (proposal writing, pilot study, community advisory, inquiry meta-map, and final public conference) and shared curricular goals across inquiry groups (author an empirically based science investigation or engineering design and develop girls' positive identities in science). Though these events and goals serve as the skeletal structure of the club experience, teachers are explicitly charged with and supported in completing the unit's instructional design by marrying their personal disciplinary expertise with youth voices through twice-weekly lesson plans, implementation and reflection. In this study, we learn from the experiences of eight preservice science teachers working individually and collectively to develop a professional identity through investigations co-developed with urban youth related to the physics of high heels, the science of baking a chocolate chip cookie, the chemistry of craving, and the science of classroom focus. Given one's own team of urban teen women for 20 consecutive sessions, each preservice teacher in a cohort balances agency and accountability to plan, implement and evaluate Science STARS' twice weekly club meetings toward a final public performance of long-term authentic inquiry. This study explores novice science

teacher learning as normative, core and personal identity development (Cobb & Hodge, 2011) evidenced in ongoing (written and oral) self-critique and goal setting framed by the following two research questions:

- How did teachers' celebrations and self-critiques reveal their developing identities - normative (who I should be) as well as personal (who I am in this situation)?
- How did participants take up and modify the structural elements of a practice-based curriculum as they moved with their "students" through a unit?

## **Conceptual Framework and Study Design**

Science teacher education programs like the one involved in this study advocate for a particular vision of science teaching and learning that is grounded in learning sciences research. Included in this vision is the co-construction of a classroom culture that engages all participants in "productive disciplinary engagement" where youth and instructors intentionally problematize scientific ideas, youth are given authority to define and conduct inquiries, participants (youth and adults) hold each other accountable to scientific (and other) standards, and all have access to essential resources for this co-constructed work (Engle & Conant, 2002). I have argued elsewhere that identity is an essential lens for science teacher learning as these professionals take up the charge to enact changes required to nurture youth learning of the disciplinary practices (Luehmann, 2007). This teacher learning as identity development is supported through opportunities to integrate one's autobiography, consider and integrate experts' voices with one's own, reflect on practice connected to but separated from practice, engage in critical inquiry-based reflection and engage in community-based interactions (Darling-Hammond & Hammerness, 2005).

STARS was designed to offer teacher-learners uncommon (and much needed) opportunities to do this work within the community of learners of their own cohort and university faculty in spaces separate from the institution of schooling, thus allowing for instructional experimentation and interpretation toward aims that are complementary to (but often missing from) school learning goals. Agency with accountability, fun with focus, and exploring with explanations are criteria for success made explicit by the program's leadership team as well as taken up in various ways by the preservice teachers.

As part of a four-year ethnographic design-based research study looking at learning and identity work of teachers and youth in a structured, out-of-schooling learning context, this paper explicitly considers the balance of agency and accountability for novice teachers in this semester-long project. Throughout the project, perspectives and experiences of all members of interrelated communities of learners (youth, teachers and researchers) informed ongoing programmatic and research-based decisions.

## **Sources of Data**

Twice weekly, across 20 weeks, each of eight preservice teachers authored lesson plans toward a final performance - a public engagement of youth's and teachers' "significant narrators" (Sfard & Prusak, 2005) centered on their scientific work of the semester. This instructional design, implementation and reflective work was done with significant, ongoing support including participation in a graduate-level methods course, written feedback on each lesson plan more than 24-hours before the lessons were taught, collaborative debriefing after each session, and weekly cohort-based video critique around a core science teaching practice (e.g. developing scientific explanations). Though a wide variety of data sources inform this study, primary data sources include written plans and reflections, as well as audio recordings of collaborative debriefs. Specifically, these data include:

- Pre-service teachers' written plans (weekly) and reflections (twice weekly) including practice-based goals, individual youth's achievements, strengths and thoughts about future work, and evidence of four key components of productive disciplinary engagement (problematising content, giving youth authority, accountability standards and resources.)
- Transcriptions of cohort-based oral daily debriefs (twice weekly) of perceived strengths and future goals from four science teachers and two university personnel.

Preliminary findings reveal a disconnect for particular preservice teachers' between their normative and personal identities with respect to the sophistication of their understandings of both science concepts and practices. This disconnect between identities extended to related risk-taking, personally and instructionally.

These same teachers differed from their peers throughout the semester in their abilities and willingness to capitalize on structured aspects of STARS (proposal writing, protocol advisory) - expressing fear, frustration or disinterest over curiosity and enthusiasm.

## **Implications for Fostering Teacher Identity Development**

Learning to teach in out-of-schooling contexts not only offers teacher-learners ongoing safe and supported opportunities to try, fail, succeed and learn (Gee, 2003) with significant university mentorship; these

experiences privilege and foreground a set of research-based proficiencies for teachers of science that are complementary to and missing from aspects of teaching and learning that are prioritized by state testing and teacher performance assessments. Included in these proficiencies are practices intentionally designed to nurture urban youths' science identities- a core aspect of equity (Cobb & Hodge, 2011). This study provides insight into innovative ways to scaffold preservice teachers' abilities with and commitments to facilitating productive disciplinary practice within the culture of science.

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# **Learning and Becoming Through Art-Making: Relationships among Tools, Phenomena, People, and Communities in Shaping Youth Identity Development**

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**Abstract:** The making of art creates possibilities for youth to simultaneously learn about what is being represented and develop their own identity in relation to the representation and how it is accepted or reacted to by others. Each paper will present a different case of students making art, how the process that they engaged in afforded different learning opportunities, and the outcomes of their participation.

## **Introduction**

There is growing concern in the Learning Sciences about the ways in which formal education is cut off from reality. Schools, even classrooms that adopt inquiry methods and ambitious pedagogies, often abstract disciplinary content away from the contexts and purposes of that knowledge—to solve complex, real world problems that are relevant to today's youth *now and into projected futures*. One consequence of hermetically sealing off schooling from real life by teaching the disciplinary content in abstract ways, with the hope that the concepts can be connected to students' passions and purposes at some later time, is to alienate students from disciplinary learning. Further, this formal education approach flies in the face of contemporary theories that recognize learning as intimately tied up with developing a sense of self and community through meaningful participation in the practices of the communities of which they are becoming a part.

The making of art—whether the medium is sculpture, film, performance, visual graphics, or new media—creates possibilities for youth to simultaneously learn about what is being represented and develop their own identity in relation to the representation and how it is accepted or reacted to by others. In fact, it is not clear if these aspects are separable at all. We see developing one's identity at the core of what it means to learn, and constructing representations at the core of the process of becoming and re-envisioning oneself in relation to the world.

## **Why Focus on Art as a Means for Academic Identity Development?**

Art is deeply personal, but at the same time is always a comment on the world as well. The genre of artistic expression that we focus on is the construction of *art with a message*. While any painting may evoke an emotion and reflect the artist's perspective on the world, we focus on cases where students are explicitly and consciously aware of creating art to critique, comment on, explore, convince others of a particular idea or create a narrative with a message embedded within the story. *Art with a message* provides an opportunity for students to start from where they are and what they know, but to direct their artwork outwards, towards an audience and a community concerned with the very subject the students are exploring. Thus, it provides youth a pathway for participation in a community that extends beyond the classroom and a pathway for the community to begin to interact with youth in ways that serve varied interests.

Additionally, *art with a message* provides a productive tension between individualistic expression and competent community participation that helps us as analysts to uncover some of the pathways and tools for identity development that remain invisible in other contexts. For example, Halverson (2013) points out that art is often treated as the ultimate personal expression, and yet there are historical conventions for art making that community members expect the artist or maker to follow or selectively break. This contradiction creates a dilemma for adults who wish to work with and develop youth identities as film-makers or artists. In Halverson's study the professional communities of film-makers that worked with youth, they resolved this contradiction in different ways—creating very different pathways for students as a result. In summary, art

making has some unique affordances to involve both students and community members in new and interesting ways as well as being a revealing context to explore identity development more generally.

### **Theoretical Framework**

There are many different theories of identity and identity development. Each scholar in the symposium has adopted a theory of identity best suited to explaining their data and context, in-line with their own intellectual history. However, our presentations will be unified by our attention to practice-based theories of identity—discursive practices, tools of the trade, and roles within a community that people use to guide and understand participation (e.g. Nasir, 2002; Wortham, 2006). Further, the presentations will attempt to theorize the relationship between practice based identity and narrative identity—theories that focus on the stories we tell ourselves that create a stable narrative of who we are (Sfard & Prusak, 2005)—in new ways. Understanding practice-based identities provide us pragmatic ways to think about the opportunities to create new pathways to become someone and support the day-to-day work of identity development.

At a broad level identity development can be examined in terms of the ontological development of the subject in relation to the goals and tools of the community (Nasir, 2002). There are often established pathways for people to move along this trajectory. Existing community members play a vital role in inviting newcomers in, modeling the practices and tools, and helping the newcomers to understand and appropriate the values and purposes of the community. These invitations mark out the long term trajectory and the ways that more competent members work with newcomers to achieve smaller milestones of competent participation. Polman (2010) argues that these negotiations between adults and youth are analogous to Vygotsky's notion of the Zone of Proximal Development calling them Zones of Proximal Identity Development to highlight that the focus is on identity rather than conceptual understanding.

At a more fine grained level of detail, our collection of papers offers a coherent look at the diversity of ways that adults work with youth in these ZPIDs. Halverson's earlier work (2013) is particularly important here. Her work documented how four different afterschool programs structured youth's production of documentary films. Her analysis focused on the various professional filmmaking tools (e.g., pitches, scripts, artist statements etc.) that fundamentally shaped students participation and products. All of the papers in the symposium will highlight the tools that students were mentored in using and how the tools contributed to and helped shape their developing identities and learning.

### **Summary of Papers**

Each paper will present a different case of students making art, how the process that they engaged in afforded different learning opportunities, and the outcomes of their participation. Polman and Graville Smith describe how the combination of aesthetic and information design in infographics authoring within an authentic data journalism internship contributes to identity development and learning. Bang, Warren and Rosebery describe their evolving research to design an artscience approach to learning focused on engaging underrepresented middle and high school youth in exploring and appropriating to their own expressive and communicative purposes practices of cultivating attention, making, critique and exhibition in relation to climate change and the human microbiome. Halverson outlines four frames that used within educational research to study of identity and details four corresponding design principals for art-making projects that help lead to the development of positive self. Enyedy et al. describe how producing an interactive mural became a site for learning about their neighborhood and urban planning concepts and becoming activists who wished to inform and persuade their community about urban planning decisions.

### **Format of the Session**

The symposia will begin with short 10-minute talks by each presenter. If space permits, we would like to give the audience 15 minutes to explore more closely the artwork generated by the participants of the various projects. This would be structured like a museum walk or a poster session, where the audience could more closely examine cases of student work and ask questions of the presenters. We would then reconvene for a 10-minute commentary by our discussant Na'ilah Nasir. Estimating 5 minutes for transition time, this would leave approximately 20 minutes for moderated discussion among members of the symposium and with the audience.

## **Becoming Data Journalists: Developing Authoritative Self-Expression through Infographics Creation for Publishing**

Joseph L. Polman, University of Colorado Boulder and Cynthia Graville Smith, Saint Louis University

"Infographics" are visually dense representations of data and information, which are increasingly relevant to mass media and social media communication. Infographics are used in both print and electronic media as a means of visualizing data and as a medium of organizing and communicating science information and arguments. A number of websites such as *Visual.ly* and *good.is* distribute infographics, and they are used in

established outlets like *The New York Times*, *The Guardian*, and *Wired*. Infographics are more than charts created from quantitative data for they involve qualitative or visual cues which their authors use to illustrate or differentiate ideas (Lankow, Ritchie, & Crooks, 2012; Smiciklas, 2012). As such, infographics are an art form with a message, combining information design with aesthetic design.

As part of a broader project on developing young adults' science literacy through collaborative infographics, this presentation will focus on how the combination of aesthetic and information design in infographics authoring within an authentic data journalism internship contributes to development and learning.

We take a sociocultural perspective on human action and learning, using the notions of mediated action (Wertsch, 1998) and identification (Wortham, 2006) over time to interpret development as a combination of trajectories of participation and identification (Polman, 2012). We are concerned with the verbal and representational discourse of participants, as evidencing changes in scientifically literate ways of thinking (Polman, Newman, Saul, and Farrar, under review). In addition, we are concerned with the zones of proximal identity development (Polman, 2010) created by hybrid activity spaces where brokering and boundary objects present opportunities for young people to engage with disciplinary content and practices of professional groups in ways that allow them to develop new identifications (Gutiérrez, 2008; Polman & Hope, under review; Star and Griesemer, 1989).

The context of this research study is a year-round out-of-school data journalism internship for high school aged youth sponsored by the Communication Department at Saint Louis University, with support from a National Science Foundation Cyberlearning grant. The internship program was established by Graville Smith in January 2013, and has included 6 to 10 youth through three cycles of infographic authoring. Youth participants are recruited from community programs and high schools in the region, with an emphasis on recruiting African-American and Latino students, as well as students with an interest in art (from a nearby arts-based charter school). For this presentation, we will focus on four teens: Areli, an African-American young woman who attends a private, all-girls Catholic school; Amy, a Latina who attends a public suburban school; Moriah, an African-American young woman who attended an urban public high school with competitive admissions, and now attends a 4-year state college; and Brian a European-American who attends an arts-based urban charter school.

Our methods are case studies focusing on the trajectories of identification and participation of these four youth in the data journalism internship. We focus on the discursive accomplishment of their making of infographics in the nascent data journalism community of practice. We conceptualize infographics as a genre of "art with a message," and relate authoring work to youth's development of authoritative voices expressing their ideas about science and its importance to the lives of potential readers, and to their development of identifications. All four of these participants entered the program with trajectories aimed at arts-related careers: Areli intended to pursue a career in animation by way of studies in computer science, Amy intended to pursue a career in animation in a context similar to Pixar, Moriah intended to pursue a career in graphic design (she is now majoring in that field at college), and Brian intended to pursue a career in the visual arts.

Our preliminary findings include the following. The development of youth identifications was positively influenced by (1) the structuring of activity in the internship, (2) the authentic expressive practices, tools, and role as journalism practitioners taken on by youth; and (3) the status of data journalism with infographics as an emerging and shifting professional arena, and the specific youth internship as a nascent effort at participatory action research. Table 1 below shows the main stages of a graphic "project diagram" created by an adult staff member at the internship; the full graphic included specific actions and tools used at the various stages of an infographic design project. It shows how the chronological flow of activity is generally from top to bottom (ideation to data analysis to design) and from left to right (making choices, exploring and communicating), but arrows based on various contingencies lead to different stages non-linearly. Youth participants use the digital note-taking tool Evernote heavily, and identify what they are doing based on this framework.

Table 1: Stages of a graphic project

	<b>Make Choices</b>	<b>Explore</b>	<b>Communicate</b>
<b>Ideas</b>	Identify Idea	Research Idea	Pitch Idea
<b>Data</b>	Determine Data	Visualize Data	Present Data
<b>Design</b>	Draft Design	Modify Design	Submit Design

The activity framework above, with on the fly support from two adult supervisors, enables these youth to carry out a complex set of practices, all aimed at designing infographics which compellingly and clearly convey the youth's understanding of science that they see as relevant and interesting to their audience (youth readers of an online and print publication). Areli's infographic about zombie bees engaged her in communicating with a scientist doing emergent research in this arena, and she applied her skills as an illustrator to the task of

scientific illustration using the professional tool Adobe Illustrator, in order to create an eye-catching and information-rich diagram for readers (see Figure 1). Amy's infographic about when people really pay for tobacco use, in terms of incidence of mouth, lung, and esophagus cancer, challenged her to find a way to convey a large amount of data on diagnosis and mortality in a way that readers could understand quickly; she used a combination of Excel and Illustrator to visualize and organize representations. Moriah struggled to balance aesthetic and informational goals in her infographic on hair relaxers, which was exacerbated by the fact that she struggled to understand and therefore represent the complex whole-to-part magnification of a relaxed hair strand. Brian's infographic about tracing the evolution of the T. Rex to modern chickens challenged his self-positioning as a "dinosaur expert" and "great artist," when he struggled with the boundaries/gaps/depth of his knowledge to translate his lifelong interest in the topic into a coherent and concise representation of the emergent science topic.

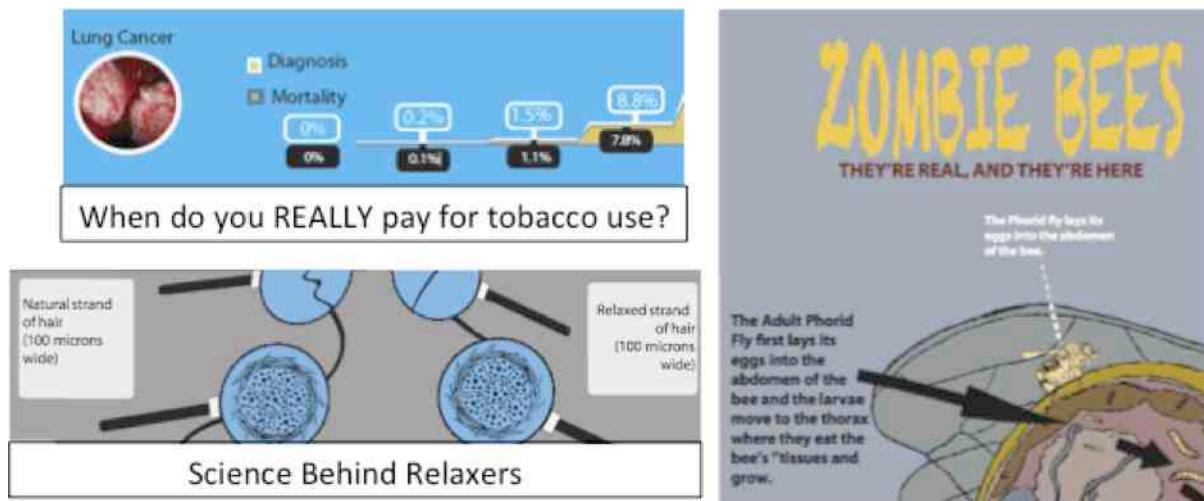


Figure 1. Detail from three science news infographics published by teen interns

These efforts benefitted from reference to authentic standards of good journalism, aimed at authoritatively conveying the current science, combined with support for aesthetic visual expression. Finally, the participants in this activity were readily able to engage in consideration of what it meant to position oneself in relation to possible selves, in part because data journalism in today's participatory, web-based media is such a moving target, and in part because their contributions to participatory action research had obvious affects on practices and tools in their own internship workplace.

We will discuss the implications of this research and development for learning environments aiming to incorporate artistic and design cultures.

## Expansive Meanings and Makings in ArtScience

Megan Bang, University of Washington, Beth Warren and Ann S. Rosebery Chèche, Konnen Center, TERC

Expansive Meanings and Makings in ArtScience (EMMAS) is a collaborative design research project focused on exploring the untapped potential of an artscience approach to learning and teaching for youth from communities historically underrepresented in science, including Native American, African American, Haitian American and Latino youth. In Seattle and Boston, two teams of learning scientists, educators, artists, and scientists are engaged in designing artscience inquiries for middle and high school youth in the domains of climate change and the human microbiome, both critically important in 21<sup>st</sup> c life. In these inquiries, participating youth directly investigate complex scientific phenomena, interpret related artistic and scientific visualizations, and develop creative responses for community engagement that integrate scientific and artistic concerns, materials and processes.

As an emerging creative movement, artscience takes many forms, all of which highlight the commonalities in thinking and making practices used by artists and scientists (Brown et al., 2011; Edwards, 2008; Heath, 1986; Jones & Galison, 1998; Root-Bernstein & Root-Bernstein, 1999; Siler, 1996). In this research, we conceptualize an artscience repertoire to include multifaceted practices of cultivating attention, making, critique and exhibition. These practices interestingly connect with those specified in NGSS but more interestingly expand them into open and varied forms of experimentation and expression that integrate across embodied and represented experience. Further, they place strong emphasis on coming to know phenomena deeply as an open process of relational understanding grounded in heterogeneity (Bakhtin, 1981) or multiplicity (Massey, 2005). Thus, as conceptualized in this project, an artscience repertoire involves youth and adults,

working together, in making and re-making relationships with phenomena, tools, materials, histories, and each other as a creative, emergent process of growth (Ingold, 2013; Nasir, 2012; Wenger, 1998). In this sense, we approach identity development as the ongoing generation and negotiation of relations within a multiplicity of possible trajectories—what Doreen Massey (2005) calls “a simultaneity of stories-so-far” (p. 12).

Broadly speaking, in EMMAS we are exploring the possibility that artscience inquiries—in their openness to boundary-crossing thinking, diverse ways of seeing, and hybrid modes of creative expression—will expand opportunities for youth from communities historically underrepresented in STEM to a) engage meaningfully in complex science and art, b) develop depth of understanding and craft in domains of significance to them and their communities, and c) erase boundaries between learning in school and thinking-acting in the larger community.

- In Seattle, Native youth, working with Red Eagle Soaring Native Youth Theater and with oceanographers and marine ecologists, are creating and performing an original play that aims at re-narrating relationships between the salmon life cycle and ocean processes beyond the dominant discourses of adaptation and mitigation in climate change.
- In Boston, students at Boston Arts Academy (a public high school) from diverse communities are working together with science and art teachers, Broad Institute microbiologists, and local artists (a data sculptor, a painter, a computational artist) to re-envision the human body ecologically as an assemblage of life forms living together—a microbiome—with major implications for health and disease.

In both sites, students’ art-making will undergo rounds of critique focused on forward-looking analysis of evolving work and work processes. Their work will be performed or exhibited in public spaces with the goal of engaged community learning and co-production of possible futures in relation to climate change, health and disease. In these ways, artscience practices potentially make available to youth multifaceted identities that cross boundaries of art and science, school and community, nature and culture.

EMMAS is in its initial design phase. Therefore, in this paper we will share preliminary analyses of artscience design activity at the two sites. We will focus on examining interactions between educators, artists and scientists as they a) engage in sustained, close looking at scientific and artistic sources in the domains of climate change and the human microbiome, and b) experiment with art-making practices in response to the sources. Through interaction analysis and discourse analysis of key events, we will address the following questions: What insights, tensions, and questions arise as the designers—educators, artists and scientists—collectively cultivate their attention to these sources? What kinds of relationships to sources and materials are generated and negotiated as they experiment with art-making? What commonalities and differences emerge between the two sites? How do these inform design possibilities for artscience inquiries in climate change and the human microbiome for youth?

## Cybermural: Becoming Artist Activists and Learning Urban Planning

Noel Enyedy, Jeff Burke, Fabian Wagmister, Amy Bolling, and Taylor Fitz-Gibbon, UCLA

Public spaces play an integral role in human life. To investigate how learning and becoming can be reconceptualized to help youth become involved and informed citizens, we linked formal education to activism by locating learning and becoming in both an after school program and in the public spaces of the youth’s own neighborhoods. The students produced public art to comment on the past present and future of their neighborhood.

Given the goals of our project we developed a set of non-traditional learning objectives. Civic engagement can be seen to have a developmental trajectory that begins with awareness and personal responsibility, grows into participation, and culminates with a critical perspective and a set of practices to constructively engage in activism and our democratic process (Westheimer & Kahne, 2004). We see digitally enhanced public spaces as an opportunity to invite new members—in particular, youth—into existing community groups, sustain their interest and scaffold their participation, and support the development of a critical understanding of community issues and relate them to larger political and institutional arrangements.

Our model for promoting civic identity development, adopted from Learning Science work in youth activism (Kirshner, 2007) and digital media production (Halverson, 2008), centered on working with an existing community group that worked with 8 high school students in an afterschool program. To study the students’ learning and identity development, we used qualitative research methods including interviews and observations. For this presentation we will present the data from the interviews, which focused on students’ self-narratives of their own identities. Pre and post interviews were compared to explore students’ changed perceptions of self and issues impacting the community.

## The CyberMural Authoring System and Process

The “cybermural” itself is a digital collage of photographs, drawings, and text produced by students that changes in response to an observer’s motion through a motion-based interaction camera system. However, from the standpoint of identity development and learning it is the authoring process, and not just the end-product, that is important. Below we outline the six phases of the authoring process where by students create art, understanding, and themselves in relation to their neighborhood.

1. **Students’ explore their community and their own prior knowledge.**
2. **Create media.** Students then create media assets (images, sound, etc.) that encapsulate some idea related to the broader themes that emerge from their exploration.
3. **Assign folksonomy keywords and weights.** The media that is gathered is uploaded in an online gallery by the students. The group revisits the conceptual discussions of step #1, and enumerates keywords (e.g., *gentrification*, *social connectedness*, *income*) that embody important concepts. Selected images are assigned tags that are “weighted” on a consistent scale (e.g., *income* on a scale of 1 to 100).

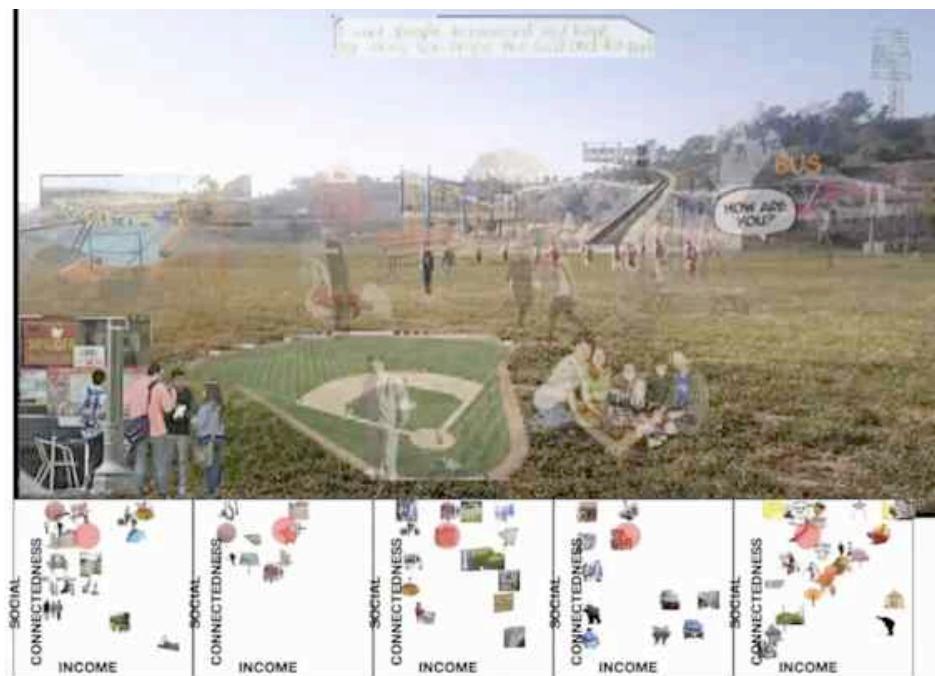


Figure 2. Building a scene from 5 different students ideograms

4. **Build “scenes” or “collections” from media.** To prepare an interactive mural, these tagged and coded media assets are now assembled into a traditional looking mural. However, the mural changes which images are displayed depending on the values of the concepts involved. For example in the mural depicted below the values are income 29 and social connectedness 82. As those values change the images such as the baseball diamond and swimming pool might disappear, while other images not present in this state appear for the first time.
5. **Map interaction to media responses via folksonomy concepts.** The concept values change based on how the audience member moves his body in front of the mural. For example, if an audience member got physically closer to the mural it might increase the “income” value, and thus change what images are displayed.



Figure 3. Constructing scenes fro five student folksonomies

6. **Present the mural.** The final phase of the project involves students presenting their mural to the public and explain what they intend the mural to show.

We began this project with a Community of Practice (CoP) perspective. We expected the mural project would be an entry point into community of practice — a site of learning and action in which people come together around a joint enterprise and in the process develop a common, historically constituted repertoire of activities, set of stories, and way of speaking and acting (Wenger, 1998). However, we came to see our project more as an example of expansive learning (Engestrom & Sannino, 2010), where students themselves contested the activity, and used the mural and the authoring process to develop a new hybrid practice that redefined the nature and purpose of their activity in the afterschool program and in their neighborhood.

## Identity, Art-making, and the Design of Learning Environments

Erica Rosenfeld Halverson, University of Wisconsin-Madison

In this paper, I wrestle with the myriad constructions of “identity” that exist in education research, describe how these constructions have been used in the design of learning environments, and unpack what we can learn about identity and design through studies of art-making. There are four primary frames that are leveraged with respect to the study of identity within educational contexts:

- Identity as a *psychological construct* that describes individuals’ internal, lifelong sensemaking process;
- Identity as understood within the context of the *sociological processes* of our everyday lives;
- Identity as defined by a series of *social categories* that help individuals and communities to identify individuals and the cultural contexts to which they ascribe;
- Identity as constructed in and through *the narratives that people tell* formally, informally, and over the course of their lives.

While these frames are not mutually exclusive, each one offers a window into how we use identity in educational research, especially as we design interventions, curricula, and community settings that attend explicitly to issues of identity in learning.

### Identity as Psychological Construct

Here, I am referring to the psychological tradition popularized by Erikson (1968) that frames identity as an internal mechanism by which we make sense of ourselves and how we fit into the world around us. This mechanism exists regardless of context, time, and interaction, but is activated by times of “crisis” when individuals experience a disconnect between their internal sensemaking and their actions in the world. Educational psychologists have favored this frame for identity and measure successful and unsuccessful development using validated measures (Marcia, 1994). Examples of designs that reflect a psychological stance on identity and development include Bers’ (2001) *identity construction environments* and Stern’s (2008) review of teens’ use of personal social media for identity development. I have considered the role of art-making in the study of psychological identity and I have found that the process of creating, adapting, and sharing original art facilitates psychological processes including exploring possible selves and creating a viable social identity (Halverson, 2005, 2009).

### Identity within Sociological Processes.

The sociological frame for understanding identity competes with the psychological, theorizing identity as constructed in the social world through interaction (Mead, 1934). From a sociological perspective there is no

identity absent presentation; identity is historically rooted but constructed anew in every interaction. Most progressive educators resonate with a more sociological view of identity and study identity-in-action using frames including individuals' "figured worlds" (Holland & Lachicotte, 2007) or the "identity kits" that are constructed through discourse (e.g. Gee, 1989). Much of the work on communities of practice as learning environments draws on sociological understandings of identity to design spaces that afford the construction and presentation of identities-in-practice (Wenger, 1998). It is perhaps obvious that the sharing or performance of original art in the context of learning environment offers opportunities for the construction of sociologically-situated identities (Halverson, 2005). Less apparent but equally as powerful is the role that the adaptation of work for public performance plays in young peoples' socio-cognitive understanding of how representation creates (and is created by) identity (Halverson, 2010a, 2010b).

### **Identity in Social Categories**

While identity as sociological process refers to the *how* of identity, we also think of identity in educational research in terms of the *a priori* social categories we assign to individuals (and that individuals assign themselves) as markers of identity. Social identity categories include race, ethnicity, gender, and social class (e.g. Kao, 2000; Phinney & Ong, 2007) but can also refer to "clique" categories defined by social group identification (Eckert, 1989). As research that evaluates individuals based on their categorical affiliation, this frame for identity is often constraining and deficit-based. However, design-based research that aims to debunk social categorization as a valid measure of positive identity development has proven a powerful method to overcome identity as stereotype (see, for example, Fleetwood, 2005; Lee, Spencer, & Harpalani, 2003; Nasir & Hand, 2008). Art-making experiences offer particular opportunities to "detypify" social categories through specific representational choices. In fact, youth art-makers often express and explore identity at the intersection among representational modes (Halverson, 2010b). It is important to remember that in art-making processes, representational choices are purposeful and that the designed learning environment serves to help youth make these choices and to reflect on them as a core part of what it means to understand the relationship between identity and art.

### **Identity as Narrative**

Narratives as constituting and constitutive of identities can be found across psychological, sociological, and social categories' perspectives on identity in education. Learning environments from Alcoholics Anonymous (Cain, 1991) to the math classroom (Sfard & Prusak, 2005) draw on the narrativization of experience as crucial to learners' positive identity construction and affiliation. Art-making is a natural match for narrative conceptions of identity – it is easy to see how if we think about identity as instantiated in narrative why creating art is necessary for young peoples' development. I have found that for young people who feel marginalized from mainstream institutions, narrative opportunities to create, adapt, and express identity are crucial to the development of positive conceptions of self (e.g. Halverson, 2005, 2010a, 2010b).

### **Design Implications for Art-making and Identity**

Regardless of which frame for considering identity we bring to bear in the design of learning environments, it is clear that art-making supports the development of positive self, especially for young people who regularly experience marginalization. For learning environments that value art-making, I consider the following principles for design:

- Draw on local community conceptions of identity as the basis for design; art-making supports both individualistic and collectivistic ways of thinking about identity;
- Engage learners in cycles of creating, representing, and sharing art so that learners can experience what each component of the cycle affords. Public sharing is especially important and is often left out of the design of learning experiences because they are difficult to organize and manage;
- Provide many opportunities for critique, feedback, and reflection. It is in these moments that young people come to articulate the relationship between their understanding of identity and how art-making supports identity construction and representation;
- Evaluate learning as both process and product, looking for the development of metarepresentational competence, an understanding of when to draw on which tools for what purposes in the expression of ideas about self (Halverson, 2013).

It is my hope that these design principles spark conversations around art-making learning environments but also help the learning sciences to think about identity as a theoretical construct more broadly in research.

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## **Acknowledgments**

This material is in part based upon work supported by the National Science Foundation under Grant No. IIS-1217052 (Polman & Smith) and NSF 1256227 (Enyedy et al.).

# **Teacher Facilitation of Whole-Class Discussion in Secondary History Classrooms**

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**Abstract:** The case for classroom discussion as a core method for subject matter learning stands on stable theoretical and empirical ground. However, much of the extant research has occurred in math and science classrooms. The four papers in this symposium examine the nature of whole-class discussion in history classrooms, and begin with the premise that teacher facilitation plays a critical role in the quality and direction of whole-class discussion about the past. The first two papers explore the nature of historical understanding, and the discursive and socio-cultural obstacles that often stand in the way of its achievement in secondary history classrooms. The second two papers take a closer look at teacher learning, growth, and reflection in leading whole-class discussion.

## **Contribution and Value to the Learning Sciences Community**

In her keynote address at ICLS 2010, Pam Grossman noted the virtual absence of the humanities in a conference dedicated to the learning sciences. This symposium seeks to answer Grossman's call on two levels: first, the four papers presented here deal with the subject matter of history and the particular demands of teaching and learning in the history classroom; second, the papers examine the nature of whole-class discussion, a method that, while not *exclusive* to learning in the humanities, certainly constitutes one of its "signature pedagogies" (Shulman, 2005). Perhaps it is unsurprisingly, then, that much of the extant research on classroom discussion has occurred in math and science classrooms. By bringing together four papers on teacher facilitation of whole-class discussion in history classrooms, this symposium contributes not only to the LS community, but to our understanding of classroom discourse more generally.

## **Overall Focus and Major Issues Addressed**

Our symposium takes a look at the nature of whole-class discussion in history classrooms. All four papers begin with the premise that teacher facilitation plays a critical role in the quality and direction of whole-class discussion about the past. The first two papers analyze classroom discourse through multiple theoretical lenses that attempt to parse the myriad—and often conflicting—goals represented and actively or implicitly promoted by teacher, students, the curriculum, and classroom norms. Both papers attempt to answer the question: what stands in the way of the achievement of historical understanding in whole-class discussion? And to what extent does teacher facilitation open or close the door to student historical understanding?

The second two papers take a closer look at teacher learning, growth, and reflection in leading whole-class discussion. One of these papers frames discussion facilitation as an improvisational method and examines two history teachers' development in discussion facilitation over the course of a semester, one of whom participates in an improv class that serves as an intervention. The other paper is a self-study of two teacher educators' facilitation of a summer workshop for history teachers on how to lead whole-class discussion. The workshop was designed to encompass the three components of a pedagogy of enactment (cf. Grossman, Compton, Igra, Ronfeldt, Shahan, & Williamson, 2009). The authors reflect on the extent to which their own pedagogy adequately modeled and reflected the pedagogies they were presenting to their teachers.

The following questions underlie all four papers in the symposium: Why is whole-class discussion important in the history classroom? What is the nature of historical understanding in whole-class discussion? What role should teachers play in facilitating discussion? What implications do these findings have for teacher education and professional development?

## **Potential Significance of the Contributions**

The case for classroom discussion as a core method for subject matter learning stands on stable empirical and theoretical ground. Theoretical justifications for classroom discussion are rooted in models of participatory democracy and reasoned discourse, as well as in sociocultural theory, which maintains that learning is situated and mediated by language, and that novices learn by observing and participating with experts in cultural activities. Empirically, a considerable body of literature illuminates how classroom discussion promotes and

supports student learning and reasoned inquiry. However, much of this research has occurred in mathematics, science, and reading classrooms. To date, none of the research on classroom discussion has examined whole-class text-based discussion in secondary history classrooms.

One big question to emerge from this body of research concerns the teacher's role in scaffolding and supporting reasoned discourse. Researchers agree that productive student discourse is unlikely to occur in a classroom where teacher talk consists *exclusively* of Initiation-Response-Evaluation (I-R-E) patterns (cf. Cazden, 2001; Nystrand & Gamoran, 1997), yet suggestions for effective teacher facilitation vary. Some researchers have recast I-R-E sequences as potentially useful under certain circumstances. Wells (1999) found instances when the "third move" of the sequence served to follow-up on, rather than evaluate, student thinking, and O'Connor (2001) distinguished between exploratory talk, when the teacher might hesitate to correct a student's misconception, and summative talk, when the teacher might review a concept in order to reestablish students' knowledge. Wolf, Crosson, and Resnick (2004) also found that the quality of student responses depended on the types of questions that teachers posed. Clearly, the teacher plays a more critical role as facilitator in whole-class discussion, as opposed to small-group discussion, where teacher involvement is at best intermittent.

The four papers in this symposium address the role of teacher facilitation of whole-class discussion in history class. In the first paper, Reisman defines the goal of text-based historical discussion as entry into the *historical problem space*, where students come face to face with the strangeness of the past. She identifies instances of substantive whole-class text-based discussion from classroom video taken over the course of six-month intervention in five 11th grade classrooms that implemented a document-based curriculum, and highlights particular teacher discourse moves that may have opened or closed the door to the historical problem space. In the second paper, Shane-Sagiv analyzes a spontaneous classroom discussion that occurred in a 10th grade high school class in Jerusalem when students learned about young socialist immigrants to early 20th century Palestine. Shane-Sagiv identifies the forces—including teacher practice—that worked to pull this discussion, and ones like it, into the present and away from historical understanding. In the third paper, Barker observes, interviews, and studies two history teachers as they teach history with discussion and reflect upon their discussion-facilitation styles. One of the two teachers participated in a 10-week "Improvisation for Professional Practice" course that served as an intervention to support the improvisational nature of classroom discussion facilitation. Lastly, Barker and Fogo present their findings from a self-study of a professional development workshop on classroom discussion that they led with history teachers. The authors discuss a promising pedagogical model for bringing practice-based instruction into professional development, and reflect on their own successes and shortcomings in implementing this model. We are fortunate that Joseph Polman has agreed to be the discussant on this panel.

We believe that, together, these papers contribute not only to our understanding of whole-class discussion in history class, but also an appreciation for the challenging role that the teacher must play in facilitating and curating educative discursive experiences for students. Our four presenters represent a range of institutions and roles. From public and private institutions of higher education in California, New York, and Israel, we are researchers, teacher educators, professional-development providers, curriculum designers, and former public-school teachers. We hope that by sharing what we have learned about discussions in high-school history classrooms, we will launch a community-wide conversation about how we might best support and prepare teachers to facilitate meaningful, reasoned, and provocative deliberations about the past.

## **Entering the Historical Problem Space: Whole-Class Text-Based Discussion in History Class**

Abby Reisman

### **Overview**

The present study examined whole-class text-based discussions in 5 classrooms that participated in a six-month curriculum intervention in 11<sup>th</sup> grade history classrooms. This study asks: (1) To what extent did the presence of inquiry-based curricular materials foster whole-class disciplinary discussion? And (2) What was the nature of teacher facilitation of classroom discussion about historical texts? Analyses explored whether relationships existed between particular teacher moves and higher levels of student historical understanding.

### **Historical Problem Space**

The framework for this study draws from the research on student historical thinking, as well as from the philosophy of history. In attempting to reconstruct the past, the historian enters into what I am calling the *historical problem space*, where the strangeness of the past butts up against the human desire to render it familiar. The strangeness of the past becomes a sticking point for students who struggle to explain unusual historical customs or behaviors (cf. Ashby & Lee, 1987; Dickenson & Lee, 1984; Lee, Dickenson, & Ashby, 1997). Ultimately, entrance into the historical problem space requires careful and deliberative reading of

historical texts, and the formulation of claims that reflect the tentative nature of historical knowledge. This study examined whether and how teachers were able to foster disciplinary deliberation and textual analysis among adolescents studying the past.

## Method

Over the course of the six-month intervention, five treatment classrooms were observed twice per week and videotaped once per week, for a total of 20 videotaped lessons per teacher, 100 videotaped lessons total. All five teachers participated in four-day summer training, and three follow-up workshops. The teachers ranged in age, years of experience, and background in history. Videotaped classroom lessons were analyzed and instances of whole-class discussion were identified using four criteria: 1) the teacher had to pose the lesson's central historical question explicitly at the start of the discussion; 2) students must have read at least two documents *prior to the discussion*; 3) the discussion had to include at least three distinct student turns that responded to the central question; 4) the discussion needed to have lasted at least four minutes. These criteria maximized the probability that the discussions would contain instances of substantive text-based discussion about the past.

Transcripts were parsed into teacher and student turns. Teacher turns were divided into two moves: "generic" and "historical". Classified as *generic* were any moves that are not particular to historical discussion, for example, when a teacher encouraged student participation or basic elaboration on a point. Historical moves explicitly prompted text-based historical argumentation. An intentional effort was made to use existing language, in light of the call to develop a "common technical vocabulary" of instruction (cf. Grossman & McDonald, 2008, p. 186), and several codes below include citations to prior work where the term was applied or coined. Here, however, the terms specify history-specific disciplinary moves: (1) *Modeling (text-based discussion)*: Teachers model how to use text to support a historical claim or how to agree or disagree with a classmate's interpretation of evidence; (2) *Revoicing (a text-based historical claim)*: Teacher reformulates/refines student text-based claim in order to highlight/clarify the relationship between the claim and warrant (cf. O'Connor & Michaels, 1996); (3) *Uptake (of text-based historical claim)*: Teacher follows-up student textual reference with a question or requests or provides a *counter-argument* (cf. Nystrand & Gamoran, 1997; Applebee, Langer, Nystrand, & Gamoran, 2003); (4) *Marking Text (for historical interpretation)*: Teacher directs student attention to a particular document and asked an interpretive question about it (cf. Beck & McKeown, 2006); (5) *Textual Press*: Teacher asks student to substantiate claim with textual evidence (cf. McElhone, 2012); (6) *Stabilize content*: Teacher authoritatively (most often through an I-R-E sequence) reviews content knowledge relevant to the discussion at hand. A final code, '*Presentist Question*,' was developed to account for instances when the teacher posed a question that was ahistorical or prompted students to turn from the documents and to bring contemporary worldviews to bear on the topic. Consequently, presence of this code was considered evidence of ahistorical discussion.

## Findings and Implications

Nine discussions fulfilled the criteria established above for substantive text-based historical discussion and these totalled 132 minutes of disciplinary whole-class discussion from over 7000 minutes of footage.. Furthermore, only three of five teachers who used the intervention materials led substantive text-based discussion. Although I cannot engage in causal or even comparative analyses, I argue that certain moves may have opened or closed the door to deeper historical understanding. By examining each teacher in turn, I suggest that presence and absence of certain moves may shed light on each teacher's beliefs about the goal of whole-class text-based historical discussion.

Due to space limitations, I will provide a single example. Ms. Addams's facilitation style was characterized by high textual press and uptake. In the following exchange she led discussion around a central question: Was Abraham Lincoln racist? As she asked each small group to report their conclusions, she insisted that students support their claims with evidence from the documents:

T: John, what did your group say?  
S1: That he was racist.  
T: That he was racist? Why?  
S1: Because the way he talks about them.  
T: Okay. What?  
S1: Because the way he talks like bad about them like they're not equal.  
T: Okay, do you have a certain document or quote that you're referring to?  
S1: (Shakes head).  
T: Okay I need that evidence. Where does he specifically say they're not equal? Document B? Can you quote it?  
S2: Where he says, um, "I agree that the Negro is not my equal in many respects."

T: "I agree that the Negro is not my equal in many respects." Okay. I know some people actually used this quote for the other side—it just depends where you end your quote. Historians can do that, right? You decide where you're going to end your quote? Because what does the rest of this sentence say?

S2: Perhaps.

T: Perhaps. Definitely in color we're not the same, which is true, right, that has nothing to do with inferior/superior, it means just saying we definitely don't look the same, and *perhaps* we're not the same intellectually. Maybe. He doesn't say for sure. So it's just, just to show you, that historians, anyone, can just decide—what do you choose to present? . . . So you can end your quote earlier.

Addams's response to S2 sheds light on her instructional goals. Addams noted that S2 quoted only part of Lincoln's sentence, and she suggests to the student that either segment of the sentence could be used to bolster a claim, depending on the position one wished to argue. The full quote reads: "I agree that the Negro is not my equal in many respects, certainly not in color, perhaps not in moral or intellectual endowment." Although Lincoln's words ring as unambiguously racist to our ears, some historians have argued that Lincoln's use of the qualifier "perhaps," in the context of a debate over slavery in 1858 before a pro-slavery audience, represented a radical departure from the views held by many of his contemporaries (Fredrickson, 1971, 1975; Wineburg, 1998).

Historians would take umbrage at the thought they pull quotes from context to support a particular view. Yet, Addams's goal here is not to illuminate the context of 1858, but rather to stress the importance of providing a textual warrant to back one's claim. The claim-warrant relationship constitutes the core of any argument (cf. Toulmin, 1958). Addams's insistence that students supply warrants to substantiate their claims reflects her commitment to their academic development and college readiness.

Why should an emphasis on argumentative warrant work at cross-purposes with careful textual analysis and entry into the historical problem space? The answer lies in how one arrives at the argument. To better understand, we must turn to a popular writing scaffold known as the "Quote Sandwich" (cf. Lieberman, 2010). In a "Quote Sandwich," textual evidence represents the lunchmeat, tucked between two slices of claim and analysis bread. While arguably useful as a structural support during the writing process, the "quote sandwich," when used as a blueprint for student text-based claims during historical discussion, inverts the inductive process of historical reading. Rather than prompting students to derive their claims from careful, collective analysis of text, the "quote sandwich" model of discussion prompts students first to stake a claim, and then to find a textual warrant to support it, even one that happens to be decontextualized.

## Implications

This study demonstrates that genuine disciplinary discussion about historical texts runs counter to many of the assumptions and expectations that both teachers and students bring to the classroom. First, popular curricular resources consistently present argumentation in discipline-neutral ways. The classroom exchanges presented here suggest that teachers will need a more robust model of historical argumentation if they are to help students engage meaningfully with historical texts. The second obstacle lies in contemporary classroom norms that champion student-centered learning and pillory authoritative teacher-centered instruction at the expense of substantive learning. Active teacher facilitation and intervention proved essential for meaningful student participation in two of the three classrooms that featured any amount of substantive text-based discussion. Furthermore, the teacher who was able to bring students into the historical problem space kept students' eyes trained on the documents by marking the text, and modeling and revoicing how to read and how to use quotes as warrants for historical claims. Furthermore, she was also the only teacher to interrupt discussion with I-R-E sequences that reviewed and stabilized content knowledge. Such a teacher-centered, didactic intervention is often seen as heavy-handed, squelching the agency of the child. Yet it is precisely these moves that pave the way to substantive historical discussion and entry into the historical problem space.

## Is Communism Against The Laws Of Nature? Or: What is the Conversation in the History Classroom About?

Chava Shane-Sagiv

In this paper I analyze a discussion from a history lesson in a tenth grade Israeli high school classroom in Jerusalem. The aim of my close reading of both the words and tone of the conversation is to demonstrate the following claims, which are based on a yearlong empirical study: (a) spontaneous student comments in ordinary history classrooms contain very little history, (b) classroom discussions of the past create very particular opportunities for challenging student assumptions and beliefs, and (c) teacher practices have a direct bearing on the value of historical lessons to both student knowledge and identity.

Data for this paper was drawn from a larger research program that aimed to explore actual student talk, practices and learning in an ordinary history classroom (with typical instruction, curriculum, and state tests). This research was motivated by the gap that exists between, on the one hand, claims as to the importance of history education advanced in both public and scholarly debates and, on the other hand, the paucity of actual empirical data on the topic.

### Theoretical and Methodological Approaches Pursued

During the course of one academic school year (eight months of instruction), I observed, took notes on and audio recorded all 42 history lessons in a tenth grade classroom in Jerusalem. I conducted monthly interviews with the history teacher and a focus group, distributed questionnaires and collected 'artifacts of practice' (Ball & Cohen, 1999). The focus, when analyzing the class discussion, was on 'student talk'. My primary goal was to ascertain what students asked about in these lessons, what they appeared to find interesting, and what they found frustrating. All of the students' questions and in-class remarks in all of the 42 lessons were analyzed, with the aim of discovering patterns of responses to content knowledge, specifically: (a) difficulty in understanding, (b) engagement, and (c) personal identification.

Preliminary codes were generated while data collection took place and then used to systematically analyze the entire set of lesson protocols. Lessons that touched upon a couple of categories were transcribed. Three areas were defined: (1) *lines of reasoning in the history classroom*: following students' talk over time analyzed in light of theories of the multiple lines of reasoning in the history classroom (Halldén, 1994); (2) *judging/misunderstanding the past/history in oral conversations*: student remarks reflecting understanding and misunderstandings of the historical content were analyzed in light of theories on sense-making of the past and history (Lee, 2005; Wineburg, 1998); (3) *blending of academic knowledge and identity/beliefs*: exchanges reflecting emotions/values were analyzed in light of discourse theories concerning the role of teacher talk in blending knowledge and belief in other subject matter classrooms (Lemke, 1990; Wortham, 2006) and in light of theories on this blending with regards to history (Wertsch, 2000).

### Findings

Consider the following exchanges recorded in a tenth grade history classroom in Jerusalem at the beginning of the 21<sup>st</sup> century. Ms. Stern, the teacher, has been lecturing (for not so many minutes) on the Jews of Eastern Europe who, in Ottoman Palestine at the beginning of the 20th century, established *kvootzot* (literally, 'groups') – collective communes in which young socialist immigrants shared housing and clothing in an attempt to avoid what they considered capitalist exploitation. In the 1920s, in British Palestine, some of these small groups turned into larger ones, which came to be known as *kibbutzim*. To this day *kibbutzim* remain scattered across Israel; many, however, have now abandoned strict collectivist practices. Nevertheless, they remain a code word in Israel for socialist/communist ideas and values.

The lesson has settled rapidly into a pretty conventional I-R-E pattern. As an example of the ways the young idealists lived in the *kvootzot*, Ms. Stern has just mentioned in passing that they 'took and returned clothes from collective stacks', she is about to distribute a historical letter from the time, when a lively conversation begins:

1. Natan: it's so dumb to live on a *kibbutz*!
2. Dana: it's actually quite fun to share the same clothes.
3. Noa: what's so fun about it?
4. Tomer: It's terrible! You live off of other people.
5. Mrs. Stern: you live according to your values. [very sharp]

From the start of this conversation it is not clear if the students are referring to life on the historical *kvootzot* of the beginning of the twentieth century, or expressing their opinions about life on *kibbutzim* today, or talking about the sharing of goods in general. All student remarks (lines 1-4) are phrased in the present tense as ahistorical opinions or questions. Nathan (line 1) dismisses life on the *kibbutz* while Ms. Stern had not used that term. Tomer expresses a harsh judgment against communal life (line 4) – but why is his tone upset if he is referring to a past way of life? Ms. Stern snaps at Tomer, employing a harsh tone herself and expressing a positive judgment of this same way of life. Student comments continue:

6. Dina: I don't like it, it's my clothes.
7. Noa: I find it gross to wear clothes that have been worn by somebody else.
8. Ido: communism is against all laws of nature.
9. Tomer: I think it's a lousy life.
10. Ido: communism is against all laws of nature! [very loud]

Once again, all student comments are directed against collective notions of life. The most extreme is Ido's claim (line 8), repeated with greater emphasis (line 10), that communism – a term that Ms. Stern had not used in this lesson – is against the laws of nature. It is at this point that – for the first time – a more hesitant and less-generalizing approach is introduced into the conversation:

11. Shira: but the people who came then had very little, and they didn't need a lot.
12. Noa: but it's not an appropriate life style anymore.
13. Tamar: but back then they came for ideological reasons.
14. Shimi: but it's against human nature! [very loud]
15. Mrs. Stern: why is trying to create an equal society and fighting against social classes against human nature?
16. Ido: but what does one aspire to?
17. Ms. Stern: They aspired to create a world without social classes.
18. Dov: wow. [cynical]

In this last exchange, Shira and Tamar introduce historic claims (lines 11, 13) into the conversation for the first time. They speak about the people of the past, distinguishing between them and those in class and using the term "they." For the different behaviors and values of these people these two students give an explanation in terms of needs and ideology, which had both been addressed by Ms. Stern in a prior lesson. However, instead of building upon these remarks, and taking the conversation back to the beginning of the 20th century, Stern chooses to respond to the repeated general statement about communism and human nature. Stern responds to Shimi (line 15) by asking a rhetorical moral question that is less about the *kvootzot* and more about not letting Shimi's response hang in the air. In response to her rhetorical question Ido (line 16) introduces a further abstract and ahistorical question. Stern tried again to promote her approach, which Dov didn't find convincing (line 18).

## Discussion and Implications

- 1) *Talking about the past is never only talking about the past.* Throughout the conversation presented above, as in most conversations across the year, the topic of the conversation shifted rapidly from past to present without this being explicitly mentioned. It wasn't easy to distinguish – during class or in retrospect when analyzing the data – who, when or what the discussion was about.
- 2) *Teacher practice influences the present-past pull.* In the lesson above, as in many lessons across the year, the teacher contributed to the shift of focus away from the past. She contributed both by what she did do – her responses, and by what she didn't do – e.g., not discussing the historical document that she had brought to class.
- 3) *Becoming often trumps teaching and learning.* In the conversation reported above, as in most conversations in this history classroom, signs of student engagement (raised voices, repetition of claims and questions, etc.) are indications that students are working through their beliefs, or desire to do so. The data suggests two surprising correlates, at least in this classroom: firstly, the same is also the case with the teacher, and secondly, (though the exchange provided above might be a partial exception) such discussions are hardly ever directly connected to the content knowledge being discussed.

Historical inquiry directs our minds and emotions to humans and human behavior – that of our own as well as that of earlier times. The nuanced addition of 'earlier times' is what distinguishes a history class from a 'civics class', a 'sociology class', and so on. The above data demonstrates how difficult it is, in an ordinary classroom, to 'stick' to the past. For history education, this finding has implications for teacher training, textbook writing and testing. Furthermore, this research has implications for teaching and learning in other subject areas, where one might find analogous scenarios of student engagement leading discussion beyond or past the subject-matter that needs to be covered.

Hundreds of people chose to live communal lives in early 20<sup>th</sup> century Palestine, a time when socialist and communist ideas were attractive to millions of people around the world. We can dismiss them all as 'dumb' and move on to the next topic, or we can pause and discuss a 'text' that sheds light on the phenomenon (using the methods my colleagues in this session are suggesting or other ones). A conversation focused on the past need not only serve as a stage from which we pronounce what we already know about who we are; it can also add to both our knowledge and ourselves.

## Improvisation and Teacher Learning: Re-imagining Habituated Forms of Interaction in the History Classroom

Lisa M. Barker

Leading whole-class discussion requires teachers to both carefully prepare and improvise based on students' contributions. How do teachers learn to do the difficult work of orchestrating a rich and, by nature, improvised classroom discussion? How might training in improvisational theatre affect teachers' facilitation of classroom discussion? This presentation addresses these questions through case studies of two high-school history teachers, Zach and Samuel, who attended a summer professional-development workshop on leading whole-class discussion. The author examined the discussions these teachers facilitated during the semester following this workshop.

## **Research Design**

Zach and Samuel taught history in different northern California public high schools. Each teacher selected one of their sections of students to focus on for classroom observations and post-observation reflective interviews collected during the fall semester of the 2011-2012 school year. Zach focused on his honors US History class of approximately 30 juniors, and Samuel chose a section of approximately 20 juniors in Advanced Placement US History. The author observed each classroom four times – twice toward the beginning of the semester and twice toward the end – and conducted post-observation interviews to learn how Zach and Samuel reflected on the discussions they led.

After the first two observations, Samuel took a course called "Improvisation for Professional Practice: Inspiring Innovation in the Workplace." Taught by Rob Carrol, this course met once a week for ten weeks and served as the improv theatre intervention. Within the course, Samuel participated in a variety of individual and collaborative exercises that invited him to try out and reflect on principles of improvisation alongside approximately 15 other professionals from a variety of relational practices (e.g., psychologists, parents, corporate leaders).

Data sources for each teacher include four videotaped observations of classroom talk, classroom artifacts used during observed talk (e.g., handouts, texts), and five audiotaped interviews. Improv intervention data sources included field notes, artifacts, and audio recordings of small-group reflection. The primary data sources used in analyses were the interviews and classroom observations. These data were used to document changes in the nature of Zach and Samuel's verbal moves during facilitation of classroom discussion, and to triangulate observed changes with reflective commentary provided during interviews. Interview transcripts were coded for evidence of how teachers understand and define classroom discussion, such as what they saw as the purpose of discussion and how they viewed the role of content, classroom climate, the teacher, and students during classroom talk.

Episodes of *extended* (i.e., lasting at least two minutes) *whole-class talk* were transcribed from the videotaped classroom observations. The author defined 'whole-class talk' as any talk format that included – through listening or speaking – the entire class (e.g., teacher-led whole-group recitation or discussion; student-led half-class 'fishbowl' discussions that all students can see and hear). Transcripts of whole-class talk were divided into *communication units*, one or more words that function as an independent clause; thus, a single person's turn can have multiple units. Each unit was coded for whether the teacher or a student was the speaker, and then by *linguistic function(s)*, or if the unit served to direct, inform, question, respond, or offer a short response (e.g., "Yeah," "Okay"). Units coded as 'respond' were subcoded for kinds of *uptake*, or the purposeful picking up on student responses in order to frame new questions (Nystrand & Gamoran, 1997). The author created a typology of uptake for the purposes of this study.

## **Findings**

Over the course of the semester, Zach seemed to change how he defined discussion and how he saw his role during discussion. As he reflected on the discussions he led, he expressed a desire to let students do more of the heavy lifting in terms of demonstrating knowledge, listening to one another, and building off each others' ideas. He characterized his original sense of his role during discussion as one who steers students toward particular historical arguments through a set of leading questions. He had since re-imagined this role as enforcing norms for active listening and uptake. This shift in vision seemed to manifest in the quality of Zach's responses to student contributions. Specifically, he used two moves to make space for student comments: (1) He made a conscious effort to let students answer questions, rather than filling in the gaps for them; and (2) he used an uptake move the author calls *Post* to encourage students to respond directly to one another. After a student offered an idea, Zach 'Posted,' or asked a question that gave the rest of the class a space to respond directly to that student's thought before moving on to a new idea.

The frequency, sequence, and quality of Samuel's questions and uptake also seemed to shift as the semester progressed. The nature of these changes, alongside Samuel's interview commentary and an analysis of Rob's debriefs of improv exercises, suggest that Samuel may have responded to Rob's teaching by noticing, naming, and importing into his history classroom aspects of Rob's style of discussion leadership. While describing what he noticed about Rob's facilitation of discussion, Samuel mentioned both Rob's overall facilitative manner and the particular moves Rob made during his facilitation of whole-group debriefs. Among

Rob's moves, Samuel mentioned the open-ended quality and sequence of Rob's questions, the generous 'wait time' Rob used to give participants time to think after each question, and how Rob responded to student contributions by mapping specific student ideas onto the essential understandings Rob wanted students to gather during the course.

There was also evidence that Samuel began to import features of Rob's *template of talk*, or how Rob choreographed questions and uptake to guide participants toward key insights about the nature of improvisation. Samuel may have imported three features of Rob's template of talk: the use of open-ended, authentic questions to launch discussion; the move of mapping student contributions onto essential understandings; and – a talk move of Rob's that Samuel didn't reference in his interview data – the use of *Press* to probe student thinking. Similar to the notion of 'conceptual press' in mathematics (Kazemi & Stipek, 2001) and reading comprehension (McElhone, 2012), 'Press' is a move in which a speaker responds to a comment with a request for further explanation, elaboration, clarification, or evidence (e.g., "Say more about what you mean by X.;" "What in the text makes you think X?").

## **Discussion and Implications**

Although the Common Core State Standards for Speaking and Listening assume that teachers are adequately prepared to explicitly teach discussion skills and facilitate discussion that promotes comprehension and collaboration, this research shows that even teachers who are very motivated to investigate and improve their facilitation struggle to do so. Across subject areas, schools, and programs of preparation, teachers consistently wrestle with how to facilitate discussion and, therefore, with how to support students in exhibiting the speaking and listening capacities outlined by the Common Core.

At the same time that this research has highlighted the difficulty of re-imagining habituated forms of interaction, it offers hope that change in instructional practice is possible. Within just one semester, Zach and Samuel used higher levels of uptake to a greater degree over time, which suggests that they may have been listening more carefully to students' contributions as the semester progressed. When triangulated with interview and intervention data, Samuel's shifts in facilitation suggest that the improv course afforded a space for experimenting with new facilitative manners and modes of interaction. The improv course provided ongoing opportunities for participants to experience, understand, and exercise the central principles of improv as well as reflect on the relevance of these principles for their professional practice. These reflections, as facilitated by Rob, offered Samuel weekly representations of the practice of orchestrating discussion. Based on interview data and the observed shifts in the quality and frequency of Samuel's talk moves, he seemed to import improv principles into his facilitation of whole-class talk.

As research takes on the hard work of investigating improv-based interventions and elusive improvisational classroom interactions, we inch closer to understanding how teachers develop and enact the capacity to respond purposefully in the moment to students' ideas.

## **Reflection on Action: A Self-Study of Pedagogy and Practice in a Teacher Professional-Learning Workshop on Classroom Discussion in History**

Lisa M. Barker and Brad Fogo

Our symposium culminates with a presentation that highlights how we have applied our research findings to teacher professional learning. In particular, we examine an intensive summer professional-development workshop on leading whole-class discussion. The authors (who co-taught the workshop) conducted a self-study designed to answer the question: What do the goals, assessments, and activities of the workshop reveal about the instructors' (1) underlying pedagogy of professional development and (2) conceptions of the instructional practice of leading whole-class discussion?

The workshop was called "Investigating the Civil Rights Era: Inquiry-Based Discussion in the History Classroom." Located on a university campus, the workshop lasted approximately 50 hours over eight days (Monday-Thursday, 9am-4pm, for two consecutive weeks) in July-August 2012, and included 16 history teachers from Northern California public high schools. The goals for teacher learning were that, by the end of the workshop, teachers would:

1. Deepen their understanding of a specific historical era – in this case, the causes and effects of post Second World War civil rights movements in the United States.
2. Understand why discussion is important and what components and moves comprise the complex instructional practice of leading whole-class, text-based discussion.
3. Be able to plan for these components and enact targeted moves, including establishing norms for interaction; selecting and excerpting rich written and visual texts to prepare for, propel, and deepen discussions; devising questions, tools, and opportunities for students to practice interacting with

texts and each other; listening actively during discussion, monitoring student participation, and using uptake to respond to student ideas; and assessing and providing feedback on discussion.

The workshop provided time for teachers to prepare for the following school year by designing and enacting discussion-based lesson plans based on topics and questions of their choosing.

This choice to build time within the workshop for teachers to plan for and rehearse the instructional practice of leading discussion exhibited our commitment to design teacher-learning experiences that adhere to Kazemi and Hubbard's (2008) notion of a 'pedagogy of enactment,' or opportunities to "simulate the sorts of situations teachers confront in the midst of instructional practice and thus engage teachers in the ways of knowing involved in classroom teaching" (p. 438). In their investigations of how people are prepared for relational professions – namely, the clergy, teaching, and clinical psychology, Grossman and colleagues labeled the three components of a pedagogy of enactment as *representations*, *decomposition*, and *approximations* of practice (Grossman, Compton, Igra, Ronfeldt, Shahan, & Williamson, 2009). The authors suggested that one way to support teachers as they acquire new practices is to structure opportunities for them to (1) observe, (2) unpack, and (3) try out aspects of real-world practice within the context of their professional learning experiences. The workshop followed this three-part framework as it modeled the practice of discourse facilitation (i.e., representations) before "breaking down [the] practice into its constituent parts for the purposes of teaching and learning" (i.e., decomposition) (*Ibid.*, p. 2058). Throughout the workshop, teachers also had multiple, carefully sequenced opportunities to enact (i.e., approximate) these decomposed practices with colleagues. Although off-site, among-peer approximations cannot be as authentic as teaching young people in the context of an actual school, they offer rich opportunities for teachers to rehearse and receive feedback on a complex set of skills in a safe, supportive, low-stakes setting.

## **Findings**

Borrowing from the work of Williamson (2006), we conceptualized the instructional moves required to lead discussion as a set of "strategies for getting students *into*, *through*, and *beyond* discussions" (p. 195). Within each of these three phases is a range of sub-practices; for example, within the 'through' phase, a teacher must listen actively and respond to students' contributions.

While we applied a full pedagogy of enactment (i.e., including representations, decomposition, and approximations of practice) to some of the sub-practices we had targeted, other components of leading discussion were given less or, in some cases, no emphasis. For example, the workshop provided opportunities for teacher-participants to observe, examine, and enact the practices within the 'into' and 'through' phases of discussion, including selecting, adapting, and sequencing rich texts of multiple genres; providing scaffolds (e.g., from simpler to more complex texts, from smaller to larger groups) that support student learning about texts and talk; to listen actively; and to respond to student thinking. Other practices – such as establishing and enforcing norms for interaction, using visual text in discussion, monitoring student participation, synthesizing the content of a discussion, and providing feedback on students' participation – although represented and decomposed, were not fully explored through structured opportunities to approximate practice. The sub-practice of self-reflection on one's own facilitation was partially approximated but never visibly modeled or debriefed. Finally, two of our targeted practices (designing questions and assessing and evaluating students' understanding), although made audible (i.e., "This is important."), were not made visible (i.e., "This is what this looks like.") nor practical (i.e., "This is how you go about doing this."). In hindsight, the 'beyond' phase of discussion received the least time and attention, and the planning and facilitation phases received the bulk of our focus as a teaching and learning community.

## **Discussion and Implications**

As teacher educators who conduct research on the instructional practices we target in our workshops, we strive to establish explicit connections between our findings and the design of subsequent professional-learning experiences. At the same time, we see self-study as a way to stay critical of our pedagogies – to be honest about the extent to which our empirical knowledge aligns with our pedagogies, as well as the extent to which these pedagogies align with our practice as teacher educators. By making transparent these cycles of inquiry, we aim to contribute to the growing body of knowledge of what makes for effective discussion leadership and what teacher-education practices best support teachers as they acquire these skills.

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# Synergistic Scaffolding of Technologically-Enhanced STEM Learning in Informal Institutions

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**Abstract:** Scaffolding is often strongly associated with the structure of classroom educational software (Quintana et al., 2004), despite originally not involving classrooms or technology (Wood et al., 2007). Tabak argued that scaffolding can be productively distributed across a learning environment's varied educational resources, proposing a "synergistic scaffolding" design pattern: "different supports that augment each other; they interact and work in concert to guide a single performance of a task or goal" (Tabak, 2004). This symposium argues that synergistic scaffolding is particularly apt for informal learning environments like museums, where visitors draw on a diverse array of technological, social, and physical resources while learning. Examples spanning collaborative data exploration, multi-context inquiry learning, mixed-reality simulations, and augmented reality exhibits are presented. Each details the educational resources either intentionally designed into the environments or appropriated by visitors as they learn. These examples highlight how designers can enhance informal learning by looking for potential synergies.

## Introduction

Informal science education shares many of the same aims as inquiry-based science education in classrooms, but is subject to a number of unique challenges not present in classrooms, like: the need to support learners with diverse experiences and knowledge, the demand that the activity be designed to fit within a short single-visit timeframe, and the requirement that the activity be able to attract the participation of learners embedded in a free-choice environment. At the same time, informal science institutions are home to a number of social and material resources not often present in classrooms, which, if properly employed, could support learning. In her conceptualization of synergistic scaffolding, Tabak (2004) proposes the framing as "an important conceptual tool in understanding how different constituents [in distributed scaffolding] interact to produce support that is greater than the sum of the constituents."

This session will delve into how the multiple learning resources available to visitors in informal science institutions can be intentionally coordinated (and sometimes unintentionally appropriated) to form synergistic supports for learning, and the implicit and explicit roles technology can play in that coordination. Papers in this session will discuss the nature of the learning performance that is being supported, and how the activity can be designed to intentionally incorporate scaffolding resources like peers, more-expert companions, interpreters, physical artifacts, digital artifacts, ancillary repositories of knowledge, and cultural tools (both the practices of the visitors as well as the practices of the target learning domain). The papers will also describe how these resources can be marshaled to perform the traditional scaffolding functions like inspiring interest in the task, reinforcing adherence to task requirements, reducing the degrees of freedom within the task, and providing feedback and repair functions.

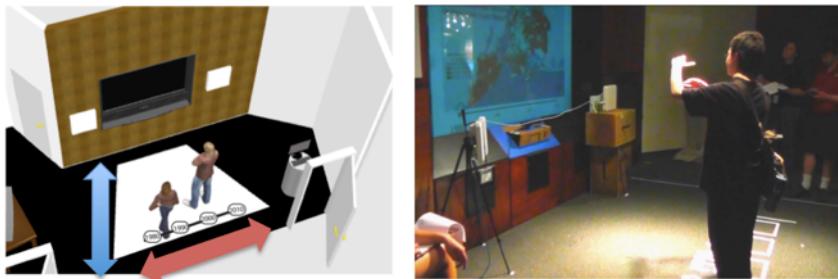
Each presentation will cover a very different type of informal learning experience, each in different stages of development: Lyons & Roberts describe how visitors drew on each other and the exhibit space itself to support joint explorations in a whole-body interaction exhibit on data visualization; Quintana reflects on the challenges faced deploying a mobile tool for bridging formal and informal inquiry learning experiences; Tscholl & Lindgren describe how the addition of a monitoring station for adults to a mixed-reality simulation exhibit activated parents as resources for guiding their children's learning within the exhibit; and Yoon, Wang, & Anderson describe how the conceptual and social learning at traditional hands-on exhibits can be transformed by the addition of augmented reality scaffolds that visualize invisible aspects of physics phenomena. Discussant Iris Tabak will lead a reflection on the array of potential informal learning resources revealed by these projects, and where appropriate, draw contrasts with the goals and designs of formal scaffolding.

## Scaffolding the Collaborative Interpretation of Data in a Museum Exhibit

Leilah Lyons, New York Hall of Science and the University of Illinois at Chicago

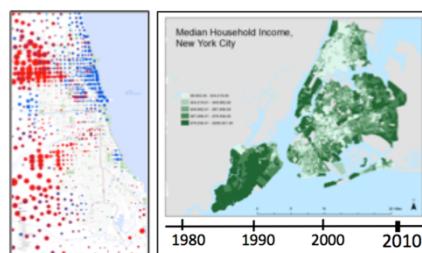
Jessica Roberts, University of Illinois at Chicago

Museums are cultural ambassadors – introducing learners to both new disciplines of knowledge and the ways-of-knowing that are privileged within those disciplines. Historically, science museums have allowed visitors to come face-to-face with the artifacts and practices of science (Conn, 1998). With our project, we address the challenge of what museums can exhibit when so much of the “stuff” of modern science is collections of organized information. How can museums present data to visitors in an accessible and engaging fashion, and how can they also inculcate a disciplinarily appropriate perspective towards data in visitors?



**Figure 1.** Left, diagram of pilot exhibit installation at the New York Hall of Science. Where visitors stand controls the appearance and the selection of the data set(s) being visualized. Right, visitors using the pilot *CoCensus* exhibit. The visitor is standing in the marked “1990” spot on the floor.

*CoCensus* is an exhibit that presents geographically-plotted U.S. Census data on a large shared display. Georeferenced census data is useful to work with because it speaks to phenomena (where people live, what people earn, etc.) that are familiar to visitors without them needing any specialized scientific knowledge. To engage visitors interactively with the data, the exhibit allows visitors to control the visualization through embodied, whole-body interaction (Cafaro et al, 2013). Where visitors stand in the exhibit gallery affects what data are shown and how they are visualized, essentially making use of the visitors and the space within the exhibit as parts of the user interface (see Figure 1). This serves two purposes: (1) it allows visitors to establish personalized connections to the data, and (2) it makes the current “state” of control immediately visible to both participating and spectating visitors. In this presentation, we use two cases to describe how users exploited two types of resources, the presence of other visitors and the space of the exhibit itself, to support the interpretations they were making of the data visualization. The cases are from observational studies in two museums: Chicago’s Jane Addams Hull House Museum (a small urban history museum), and the New York Hall of Science (NySci, a large interactive science center).



**Figure 2.** Left, a scaled centroid map showing the distribution of British-born (blue, embodied by Belle) and Polish-born (red, embodied by Peg) residents of Chicago. Users cause their data set to become more opaque (closer to the display) or transparent (farther away) by moving perpendicular to the display (see blue arrow on Figure 1, left). Right, a chloropleth map of median household income data represented as five quantiles in New York. Moving across the marked timeline on the floor changed the decade (see red arrow on Figure 1, left).

Tabak highlights “coconstitution” as an important part of synergistic scaffolds, wherein: “different constituents interact to produce support that is greater than the sum of the constituents” (Tabak, 2004). With *CoCensus*, each visitor uses a kiosk to fill out an abbreviated US Census form, and their responses are then associated with a Radio Frequency ID (RFID) badge they wear in the exhibit. This allows the exhibit to display the data subsets relevant to each user in the exhibit, and thus the exhibit’s appearance depends on the number and chosen identities of the visitors present (Roberts, Lyons, & Radinsky, 2012). Some visitors took advantage of the co-presence of data to engage in reasoning that would never have occurred with a single data set. For

example, in one trial two adult women (“Belle” and “Peg”) assumed control of the British-born and Polish-born residents of Chicago, respectively (Figure 2, left). After moving backward and forward to reveal each others’ data sets, they very quickly noted the difference in the sets’ distribution:

Belle: It looks like I'm along the lake.  
Peg: And I'm not. ((laughter)). Polish are inland. We're farming folk!  
Belle: We're sailors!

The juxtaposition of the two sets caused the women to notice a difference in the distributions, and to begin generating playful hypotheses about why. They proposed other possible differences:

Peg: You're right, you're sailors!... So right, we have no idea... that's... if you're in the, if you're in the upscale? ((laughs))  
Belle: I would think so...  
Peg: I think so too. You're by the water. It's more expensive.

The women incorporated prior assumptions about how geography intersects with property values and made further playful inferences about what this might mean about the lifestyles of the residents depicted on the map:

Peg: So you're partying and I'm there in the fields.  
Belle: Right, I'm having (all the fun).

While these women lacked the expertise to have made the same hypotheses that, say, sociologists would, their process of making these hypotheses isn’t so far from what an expert might do: (1) first notice a pattern in the data, (2) draw upon their prior knowledge to hypothesize about possible reasons for the patterns, and (3) make inferences about what impact the observed patterns might have on the lives of the represented people. The coconstitution of the women’s respective data sets was what made this fanciful exploration of the data patterns possible. What was missing from the exhibit was support for the visitors to test their hypotheses. Ongoing design iterations of CoCensus have incorporated additional data sets such as vocational information, income data, and household size. .

“The principled design of distributed scaffolding should include an attempt to create cohesion and direct interaction between the elements of the scaffolding system” (Tabak, 2004). With formal scaffolding, this recommendation often bears literal design implications, like using the same semiotics across different learning resources. With *CoCensus*, we see interacting visitors bring in spectating visitors to support their data explorations, and the spectators in turn use their observations of the position of the interacting visitors to shape their contributions. The space of the exhibit itself is thus playing an active, cohering role, as illustrated in the following case. A college-aged daughter, Kim, was interacting with the timeline of the chloropleth income map (see Figure 2) when she noticed a phenomenon of interest and engaged her parents (Julie and Ken):

Kim: ... Dad, do you know what area that is?  
Ken: Which?  
Kim: That area that's turning from white to middle green? Right there?  
Ken: Um, let's see. The bottom note. No, no wait. I'm sure that's Queens, but I'm not sure ((Really)) if that's near us or not. I don't think it is.  
Julie: And it went back to white!  
Kim: Interesting.  
Julie: In twenty years  
Kim: Ten. Well, within the space of twenty years, it has uh, from white to green to white again. That's what I mean. Um. Uh, from white to green to white again.

Here, the mother, Julie, is not just observing the change in the data visualization highlighted by Kim (“And it went back to white!”); she has also clearly been attending to how far along the timeline on the floor her daughter had been moving (“In twenty years”). This contribution added to Kim’s interpretation of what duration of time was needed to truly characterize the interesting change in the data. Kim had been thinking of it as a 10-year change, but the point her mother made forced her to realize that 20 years was needed for the odd pattern (low-then high-then low) to emerge. Julie’s attention to Kim’s movements on the timeline illustrates that the exhibit space helped the “scaffolding elements” (the visitors) cohere into unified support for data exploration.

These cases show how informal learning environments can make creative use of two oft-overlooked features (the presence of other visitors, and the space of the exhibit) to support the engagement with and joint exploration of data visualizations. We are currently exploring how to give visitors a more disciplinary

perspective by engaging them in critically challenging what data can tell them, and conversely, letting their assumptions be challenged by the data, paralleling work in classrooms (Radinsky, Melendez, & Roberts, 2012).

## The Issue of “Fit” between Formal and Informal Contexts to Facilitate Synergistic Scaffolding

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The Zydeco project is exploring how mobile and cloud technologies can support middle/high school scientific practices and inquiry activity spanning across formal classroom and informal out-of-class contexts (Quintana, 2012). The Zydeco system includes an app for iOS devices, along with a corresponding web application to provide scaffolded workspaces that support different scientific practices, including: (1) A *planning workspace* to set up a project with investigation questions and sub-questions, possible hypotheses, and labels or tags to describe and organize data, (2) a *data collection workspace* to collect different kinds of data, information and observations in the form of photos, videos, audio notes or text notes, (3) a *review workspace* to access and review the different items that have been collected, and (4) an *explanation workspace* to develop an explanation by using a “claim-evidence-reasoning” model (McNeill & Krajcik, 2011). The goal is to explore the notion of “cross-context inquiry” that broadens the settings, supports, and resources available to students so they can integrate different experiences and information into their inquiry activity. The notion of cross-context inquiry provides a setting to consider the potential synergies between the formal and informal contexts where students are undertaking their scientific inquiry. Closer integration of the formal and informal contexts is facilitated by the mobile and cloud technologies in Zydeco, which increase the *contextual permeability*, allowing students to engage in different scientific practices in and draw from resources in the different contexts, and *contextual transference*, allowing students to transfer different aspects of their inquiry activity between contexts (Quintana, 2012).

While such tools can open up larger, richer settings for inquiry projects in multiple contexts, students still face different challenges and issues. Many of the challenges that have been previously identified for students engaging in inquiry activity still apply, such as the challenges for managing the inquiry process, making sense of different ideas and information, and reflecting on and articulating different information about the inquiry activity (Quintana et al., 2004). In some respects, expanding student inquiry to span formal and informal contexts may exacerbate these challenges because students are now working in contexts that each have different goals, levels of support, and cultures. As we continue to explore cross-context inquiry, we see additional challenges in terms of the “fit” between formal and informal contexts (Quintana, 2013). For example, there are issues of (1) “cultural fit”, or the challenges arising from the potential mismatch between the goals and cultures of different formal and informal sites, (2) “resource fit”, or the challenges faced in making sure that the resources available in a given informal site fit the curricula, goals, and projects being developed in the formal classroom context, and (3) “supportive fit”, or the challenges of identifying the scaffolding needed to support not only the different aspects of the scientific practices students are engaging in, but also the resources that students may encounter in the different contexts.

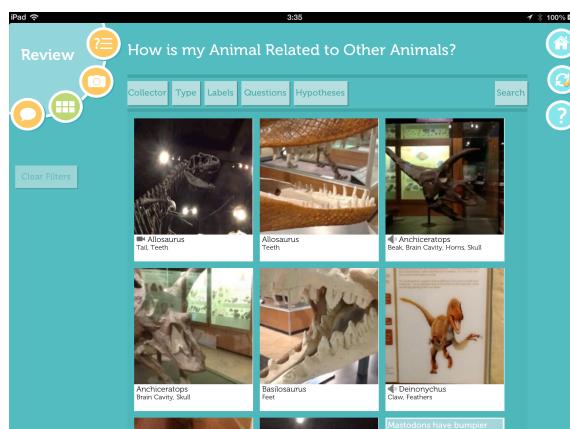


Figure 3: The Zydeco Review workspace allows students to review the data they have collected in their investigation to see what they may use as evidence in their investigation. Students can filter their data, and also view their peers' data in certain cases.

A potential benefit of cross-context inquiry is that there are conceivably more resources available to students to support their work, especially in different informal settings that can include museums, nature parks, etc. There are also supportive resources available to students, which can range from teacher and peer support in

formal settings, to signage and docent support in informal settings, to technology-based support in tools like Zydeco that aim to include supportive features that can be used in both the formal and informal settings. This collection of resources provides a potential for more synergistic scaffolding for students (Tabak, 2004)—if these different resources can be marshaled to work together, then students could potentially benefit from more cohesive supports targeted to work together to support the inquiry aims of the student and teacher in all the settings where the inquiry activity is taking place.

However, the potential synergies between these various supportive resources can be hampered because of these issues of “fit” that emerge from mismatches between formal and informal settings. For example, in a recent Zydeco trial that spanned an academic year in a Detroit middle school, our teacher was devising an inquiry project around energy. The goal was to use engines as artifacts to study different ideas about energy transformation. The potential synergies here would include classroom discussions about energy and engines, a museum visit for information gathering in exhibits on engines and automobiles, and a set of tags or labels in Zydeco describing energy concepts so students could focus on and annotate their observations and collected data about the energy projects. However, this potential synergistic trio lacked cohesiveness: exhibit signage was aimed at a general audience and there were concerns from the teacher that it would not be helpful to students, the classroom discussion did not always mesh with the material in the museum, and the student use of Zydeco labels that may not always be consistent. This episode led the team to consider ways of adjusting these activities and supports to operate in a more synergistic way. For example, we have begun to employ “mini museums” in the classroom to augment the classroom discussion with engine models that prepare students for the more complex museum exhibits they will visit. We are also considering how to better incorporate data labels within Zydeco so they go beyond an organizational tagging aid, but also reflect important aspects of the classroom discussion to serve as a reflective support that can guide data collection. And our teacher even asked whether an augmented reality approach would be feasible at the museum so that students could use their mobile devices as “viewers” to gain additional, dynamic information about how engines work when they visit the static engine models, again to augment the classroom discussion in ways that concretely illustrate the energy concepts being discussed.

These ideas point to the issues about the fit between the formal and informal context, and how trying to improve that fit could facilitate more synergistic supports between contexts. How can we improve the fit between the inquiry questions and plans in the classroom and the resources in a given museum so that the resources complement and augment the ideas and discussions in the classroom? How can we augment the signage and information in a museum with additional scaffolding to help students with sensemaking activity at the exhibits in ways that connect with their inquiry goals? Ultimately, the promise of effective cross-context inquiry is contingent on effective scaffolding across those contexts, and given the differences between formal and informal contexts, and the challenges that arise because of these differences, addressing these issues of fit may be necessary to develop a more cohesive, synergistic approach to supporting students and educators.

## **Scaffolding Productive Learning Conversations around Mixed Reality Simulation Technologies in Informal Spaces**

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There is a recognized potential for furthering learning through social interaction in informal environments, particularly parent-child guided participation (Ash, 2003; Zimmerman, Reeve & Bell, 2009). Augmented reality (AR) and mixed reality (MR) technologies, which are increasingly being used in informal spaces such as science centers, have the ability to enhance social interactions that can lead to powerful learning experiences (Dunleavy, Dede, & Mitchell, 2009; Yoon, Elinich, Wang, Steinmeier, & Tucker, 2012a). How to most effectively facilitate productive learning conversations that both leverage the visual affordances of AR and MR technology, as well as the epistemic supports offered by accompanying parents and other adult visitors is a question that requires further examination. To investigate this area of learning design and attempt to create instances of ‘synergistic scaffolding’ (Tabak, 2004), we placed an interactive and immersive simulation into a science center and configured the spatial setup and access to information so as to create knowledge dependencies between a child—directly interacting with the simulation—and parents positioned as active observers. The objective was to understand how our configuration and similar socio-technical designs support everyday interaction, as well as elicit forms of conversational interaction recognized as being particularly effective for generating learning.

The MR simulation environment utilized in our research is called *MEteor*, a full-body immersive simulation of planetary astronomy designed to help children learn about gravity and how objects move in space. Due to its significant footprint in the museum exhibit hall (a 30 by 10 foot interactive floor space) and vivid sound and visual effects, the simulation attracted considerable attention, and middle-school aged children who visited the science center with their families were invited to participate for approximately 15 minutes. The participating child was asked to carry out a set of 4 interrelated tasks that required an understanding of the effect

of gravity on the trajectory of a launched asteroid (see Figure 4a). For example, in one of *Meteor*'s levels the child was asked to hit a target located behind a planet. This required understanding and leveraging the planet's gravity to bend the asteroid's trajectory around the planet. The simulation was set up to resemble a space exploration control station with the child playing as the asteroid inside the simulation and parents and visitors situated at the sidelines invited to help. The objective was to create knowledge dependencies that would elicit conversations pertaining to the child's strategies inside the simulation and the important science concepts that dictate the behavior of the simulation. To this end we made 3 display screens visible only to the onlooking parents (see Figure 4b) that provided 1) explanations about physics principles related to gravity and orbits, 2) a replay of the just-completed launch showing the trajectory of the asteroid and the child, and 3) text giving suggestions for how to prompt the child in particular ways. The child interacting in the simulation is given a first-person perspective on the action as they launch the asteroid, but there is the potential for their performance to benefit from the knowledge and supports that can be provided by the parents.



**Figure 4.** (a) A child using her body to launch an asteroid into a target given the presence of a strong gravitation force (i.e. a planet). (b) A series of display screens visible only to observing parents and other visitors giving replay and other supplemental information about the child's performance.

The setup creates multiple overlapping—and ideally synergistic—spaces within which activities conducive for learning can occur. The child's natural body movements are placed within a simulation scaffolding the development of new intuitions about how objects move in space through visual and auditory feedback. Parents observe the child's activities and can infer her strategies and her thinking, which enables them to give timely and contingent feedback on her performance. Parents themselves are scaffolded by the visual displays providing more formal information about laws of physics and gravity. They are further encouraged to prompt the child to maintain a higher-level perspective on the game activities, specifically to think about the relationship between how the asteroid was launched (position, velocity, etc) and its subsequent trajectory. With this configuration parents have the unique opportunity to make the child's thinking and activity meaningful in relation to scientific terminology and underlying principles.

We developed a coding scheme aligned with current informal learning research (Tare, French, Frazier, Diamond, & Evans, 2010; Crowley, Callanan, Jipson, Galco, Topping, & Shrager, 2001) that was used by our researchers to annotate the talk and action while on site. We found that the parent-child interactions can be distinguished into 2 broad categories:

1. *didactic interaction* (coaching) of the child with the child carrying out the instructions
2. *dialogic interaction* between child and parents that included valuable conversational moves such as explanation, and invitations for reflection

Primarily didactic interaction occurred in 46 sessions out of 85 where parents participated in some form (54%), while in 33 (39%) sessions some conversational moves typical for dialogic interaction were identified (in 6 sessions parents participated only through encouragement or affective comments). Interactions placed in this latter category included requests for explanations ("what do you think happened here?"), offering causal explanations in scientific terms ("your asteroid got pulled by gravity"), or descriptions of what happened in the simulation in scientific terms ("did you see? There is gravity"). Often parents would engage in lengthy exchanges aimed to elicit children's knowledge, reasoning and planning, as exemplified in the following excerpt:

Dad: Tom, do you see the planet?  
 Tom: Yes"  
 Dad: What do planets do?

Tom: They attract things  
 Dad: Correct. So, do you see what is going on here?  
 Tom: I have to shoot it this way ((curving gesture))

In contrast, the ‘coaching’ type of engagement typically focused on how the child had to set the spring (“pull back more”) or the child herself (“run faster”). Prediction and reasoning were, in the didactic situations, done by the parents, with only the action of the manipulation delegated to the child. Through this first analysis, it became evident that dialogic exchanges consisted primarily of parents ‘eliciting explanations’ from children and ‘providing explanations’ themselves. Providing explanations was more prominent and occurred in all 33 ‘dialogic’ sessions; in 26 of these sessions parents in addition asked the child to provide explanations and reflect.

Our analysis suggest that when digital technologies are used in informal learning environments—even MR or AR technology that embeds a learner within an immersive simulation—parents actively work to create learning opportunities for children, guiding their attention and engaging them in critical concepts relevant for understanding the simulation. The various strategies that parents employ include elicitation of explanations or requests for knowledge. Parents model problem solving strategies, a form of scaffolding that has been linked to children’s development of metacognitive competencies (Klahr, 2000; Zimmermann, 2000). We have shown, however, that parents’ contributions to digital interactions do not only convey explanatory or descriptive knowledge, the kinds of conversational acts typically identified by studies of “static” exhibits (e.g., Tare et al., 2010; Crowley et al., 2001). The parental interventions in our study frequently aimed instead to create a space for the children to think and reflect – a space that they are left to fill on their own.

## **Using Augmented Reality to Scaffold Learning about Conceptually Challenging Science Content in a Science Museum**

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Increasingly, informal science environments have been characterized as important venues for learning science and influencing participation in science activities and careers (NRC, 2009). Questions that have arisen from this focus include the extent to which visitors can learn the science, what supports are needed, and how technology can aid in the learning (NRC, 2009). At the same time, augmented reality (AR) technologies have been highlighted for their enormous potential to enable people to construct new understanding (New Media Consortium, 2012). By layering digital images over real world environments, the hybrid display of phenomena provide scaffolds for users to experience and perceive virtual elements as part of their present world, making normally invisible things visible. In informal museum spaces, a number of studies have shown that AR can enhance visitor exploration of objects (Szymanski et al., 2008), increase visitor collaborative interactions (Asai et al., 2010), and improve interest in the content of museum exhibits (Hall & Bannon, 2006).



Figure 5: Bernoulli Blower

Building from these bodies of research, over the last several years, our project entitled *Augmented Reality for Interpretive and Experiential Learning* (ARIEL) has investigated how augmented reality and various forms of learning scaffolds can improve visitor scientific knowledge in an informal science museum setting. To date, three pre-existing exhibit devices have been modified to include digital augmentations. We selected these devices because the same or similar ones are present in virtually all science museums and centers across the world. The first device, “Be The Path”, was augmented to show the flow of electricity when visitors complete an open circuit; the second device, “Magnetic Maps”, was augmented to visualize the magnetic field surrounding two bar magnets; and the third device, “Bernoulli Blower” (depicted in Figure 5), was augmented to feature the

interactions between two types of air to keep an object afloat. Results from quasi-experimental studies on the first two augmented devices demonstrate that AR can increase conceptual (content) understanding (Yoon et al., 2012a) and cognitive (theorizing) skills (Yoon et al., 2012b). We have also shown that this learning is largely influenced by collaboration between peers and the AR device (Yoon et al., 2012b), dynamic visualization affordances (Yoon & Wang, *in press*), and preservation of informal participation such as self-directed experimentation (Yoon et al., 2013).

In this study, we investigate learning affordances of the third device “Bernoulli Blower” to scaffold learning about a conceptually challenging scientific concept. The exhibit features a plastic ball that is able to float in midair because it is caught between the fast moving air that is being blown out of a blower attached to the exhibit device and the normal, slow-moving air in the room. Although the normal room air moves at a lower speed than the faster moving tube air, it exerts greater pressure onto the ball and is therefore able to keep the ball floating in the stream of fast-moving air instead of being blown away. This idea – that speed and pressure of a moving fluid are inversely proportional – is extremely counterintuitive to learners. Studies have shown that most people believe that pressure should be high where speed is high (Faulkner & Ytreberg, 2011). Considering common daily experiences, such as observing how wind moves objects around in proportion to how strong the wind blows, this belief is not surprising. Furthermore, literature reveals that children often recognize air pressure by its movement (Sere, 1982). Where there is no perceptible movement, they think that pressure does not exist (Basca & Grotzer, 2001). In standard K12 science curricula, Bernoulli’s Principle is also often not taught by physics teachers who either lack a clear understanding of the concept themselves and/or find it too difficult to explain to students (Hewitt, 2004). Given these teaching and learning difficulties, we were interested in investigating how digital augmentations could support the learning of highly challenging science concepts. We hypothesized that the addition of AR could help students visualize the behavior of air and air pressure, which would provide a valuable scaffold for students to build better knowledge of the science behind the floating ball.

We tested this hypothesis with 58 middle school science students who visited the museum on a field trip. Students were randomly placed in one of two conditions: condition 1 (device with no augmentation); or condition 2 (device with augmentation). Through interviews conducted with students after they interacted with the device, we measured student content knowledge of the Bernoulli Principle by asking the question, “What were you supposed to learn from this device?” Responses were measured on a five point Likert-Scale ranging generally from limited understanding (1) to complete understanding (5). An independent samples t-test was conducted to compare the amount of content knowledge gained in the two conditions. Results showed that there was a significant difference in the knowledge scores of students in condition 1 ( $M = 2.66$ ,  $SD = 0.55$ ) and condition 2 ( $M = 3.1$ ,  $SD = 0.77$ );  $t(56) = -2.543$ ,  $p = .014$ . In condition 1, 38% of the students had a level 2 understanding (defined as providing simple observations or listing objects or concepts presented) and 59% had a level 3 understanding (defined as identifying a relationship between two of three variables – air speed, air pressure, and the floating ball). Only 2% reached a level 4 understanding (defined as identifying a relationship of both air speed and pressure and the floating ball). In contrast, in condition 2, only 17% had a level 2 understanding. Although there was a similar frequency of level 3 responses, 21% reached a level 4 or 5 understanding (defined as recognizing a relationship between varying air speeds and pressures and the floating ball). These results suggest that the digital augmentation had an effect on students’ content knowledge.

A perusal of student responses illustrates how the AR impacted their learning. One student (ID6) in condition 2 who scored a level 5 said, “It helped you see the air currents that was coming from the tube and it helped you see the high pressure air that was coming in from below and above. If air is moving quickly, it has low pressure. If it’s moving slowly, it has high pressure.” This student went on to explain that the activity was different from how they normally learned in school because of the screen and the display where she could “experience what it was instead of reading about it in a textbook”. She and two other girls also “tried to play a game” where they had to “get the ball to move around without completely cutting off the air current”. Here we can see that the student was able to build an accurate understanding of the phenomena while at the same time engaging in self-directed experimentation, which is an archetypal characteristic of informal participation. In the symposium, we will present additional data from the interviews that provide further illustration of how the AR provided other visualization scaffolding for students.

In this study, we examined whether and how augmented reality could be used as an effective scaffold to help visitors learn about difficult scientific concepts in the museum setting. Our findings showed positive gains as a result of student interaction with the digital scaffolds. However, similar to our other studies, we also found that there was room for even further growth in conceptual knowledge gains. Looking forward, we are considering additional ways to scaffold the experience to induce greater learning while at the same time preserving the informal experience. Designing for content understanding will inevitably require increased scaffolds, some of which are already common practices within museums such as grouping exhibits into clusters based upon conceptually related content and including advanced organizers (Falk, 1997). In our future work, we will investigate various aspects of multiple exhibit design with the addition of AR to understand how content learning and engagement can be maximally supported.

## Conclusion

Traditional scaffolding functions like inspiring interest in the task, reinforcing adherence to task requirements, reducing the degrees of freedom within the task, and providing feedback and repair functions, take on a very different form outside of the usual formal classroom settings. The examples above all demonstrate the ways in which different resources were marshaled to support some or all of these features. For example, *CoCensus* and *MEteor* engage learners' interest by "personalizing" the exhibits in different ways: *CoCensus* allows visitors to see data that reflects "them" or their choices on a shared display, while *MEteor* allows visitors to "role play" as heavenly bodies. *Zydeco* helps learners adhere to task requirements by allowing visiting schoolchildren to quite literally carry a bit of their pre-visit planning with them, and pares away unnecessary degrees of task freedom with an interface structured to place the focus on the desired information gathering activities. The *ARIEL* exhibits show how coherence between visitor actions and visualizations of invisible forces can provide necessary feedback to visitors who would otherwise struggle with the exhibits, allowing them to adjust their interactions to hone in on the core content of the exhibits.

All of these examples have designed features that work to synergistically recruit and employ other people to support learning, bringing these examples of scaffolding closer to the original tutor-to-pupil definition of scaffolding (Wood, Bruner, & Ross, 1976). The large displays and material properties of the *ARIEL* exhibits, *MEteor* (along with the side display), and *CoCensus* (along with the use of the floor space) all allow spectators to develop richer understandings of what participating visitors are doing with interactive exhibits, so that they can provide counsel and guidance. With *Zydeco*, the guidance of the teacher's counsel gets somewhat reified within the software itself by the collection of pre-selected tags, so that the students carry the teacher's guidance with them.

Each of these projects also illustrates some of the challenges that are unique to scaffolding learning in informal learning environments. The challenges with using *Zydeco* highlight how museums, despite ostensibly being settings which support open-ended inquiry learning, often lacked the curricular fit needed to support the inquiry learning questions students would generate. *ARIEL* showed how conceptual learning could be improved with augmented reality visualizations, but Yoon et al. warn that attempts to add additional scaffolds to attain even greater learning gains must be balanced against not making the activities too highly-structured and school-like, lest students lose interest. *CoCensus* showed that visitors were surprisingly ready to engage in joint explorations of data visualizations, but might be too willing to accept shallow and naïve interpretations. *MEteor* hints that sometimes the best way to employ parents as learning resource is to (quite literally) get them to step out of the way. Synergy does not magically result by combining learning resources. Informal learning designers should be sure to take into account not just individual learning resources in their designs, but to consider how the alignment across the social, material, and cultural resources in informal settings to produce learning experiences that truly exceed the sum of their parts.

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## Acknowledgments

The work presented here was supported by the following grants: NSF INSPIRE 1248052 (Lyons & Roberts), NSF DRL 1020027 (Quintana), NSF DRL-1114621 (Tscholl & Lindgren), and NSF DRL 0741659 (Yoon, Wang, & Anderson).

# **Education for Sustainability and Resilience in a Changing Climate**

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**Abstract:** Educators, researchers, planners, and policy-makers are faced with the challenge of preparing current and future generations for adaptation to the impacts of climate change. Pedagogy related to living sustainably and creating resilience is a complex field of educational practice that involves cognitive, social, and affective aspects of teaching and learning such as environmental decision-making both in a reactive and an anticipatory framing; learning in both formal and informal environments; learning to understand complex systems; and understanding both scientific and socio-cultural aspects of climate change issues related to sustainability and resilience. This symposium brings together a set of diverse research projects that, together, shed light on teaching and learning about sustainability and resilience in a changing climate.

## **Introduction**

The disparity between ecology (which is cyclical) and contemporary production and consumption processes (which are relatively linear) gives rise to unprecedented structural violence and human rights abuses (Bales, 2004) as well as climate change and related effects such as atmospheric and oceanic warming, extreme weather events, reductions in snow and ice, and global mean sea level rise (IPCC, WG-I SPM, 2013). This structural violence and climate change can be traced back to issues of sustainability and resilience across environmental, health, and social factors (Adamson, Evans, & Stein, 2002, Orr, 2012). Thus, the research presented in this symposium is directed at designing educational interventions to catalyze positive social action that addresses the unsustainability of and lack of resilience in contemporary attitudes, behaviors, and consequent systems of production and consumption.

According to Orr (1992), this truly global crisis of unsustainability is “qualitatively different, without any historical precedent” and “unprecedented in its sheer complexity” (p. 19), transversing energy, resource use, climate, waste management, technology, cities, agriculture, biological diversity and resilience, international security, politics, and human values — a clear and urgent mandate for rejuvenated participation in civic culture, and “an ecologically literate and ecologically competent citizenry” (p. 1).

Educators, scientists and policy-makers are thus faced with the challenge of preparing current and future generations to make decisions that will mitigate the effects of, and allow us to adapt to, the severe impacts of structural violence and climate change. Learning about sustainability and resilience are essential elements of how communities around the world can change their ways of living and adapt to the changing environment, which is, in turn, essential to ensuring human resilience. As Orr (1992) writes, “The goal of ecological competence implies a different kind of education and a different kind of educational experience that develops the practical art of living well in particular places” (p. 84).

The related attitudes and behaviors are complex and dynamic, and likely influenced by personal experience and knowledge, as well as cultural and political knowledge and values systems. For example, research has shown that cultural and political values play an important role in how individuals understand climate science (Leiserowitz et al., 2012). These cultural and political values also influence what actions individuals are likely to take based on their understanding of the science of climate change (Leiserowitz & Smith, 2010). Estrada's (2011) Tripartite Integration Model of Social Influence (TIMSI), suggests that supporting climate change related behaviors involves individuals (a) gaining self-efficacy; (b) identifying with concern about climate change, and; (c) adapting to the values of that group. However, the learning processes by which individuals negotiate the aspects of TIMSI while understanding climate science and its impact on their everyday life are not well understood. Helping people learn about the science of sustainability and resilience is complex enough that even those that are knowledgeable about climate science struggle to incorporate knowledge about climate change into their everyday lives (Pidgeon & Fischhoff, 2011). Understanding the content, incorporating the content knowledge into decision-making in everyday life, and using the content knowledge to conceptualize sustainable mitigation and adaptation strategies requires learners to not only connect their own actions to consequences, but also to change attitude and behavior patterns.

Research in sustainability, resilience and environmental adaptation addresses the learning goals of (a) understanding issues of sustainability and resilience across spectra –from the personal to the global– and (b) being able to situate one's self within various systems and subsystems. Pedagogy related to living sustainably and creating resilience is a complex field of educational practice that involves cognitive, social, and affective aspects of teaching and learning. More specifically, educational considerations include (but are certainly not limited to) environmental decision-making both in a reactive and an anticipatory framework learning in both formal and informal environments, learning to understand the complex systems of climate and ecosystems, and understanding both scientific and cultural aspects of the problems at hand, such as climate change.

While all of the above aspects of related pedagogical practices are being studied discretely within the learning sciences, we propose a systems approach to the topic, the pedagogy, and the related processes of teaching and learning. Learning to adapt and build resilience requires individuals to: (a) learn how to make sustainable decisions (Atran, Medin & Ross, 2005); (b) learn how to anticipate problems (Hewson, 1992); (c) learn within their informal and formal environments (Bell et al., 2009); (d) learn to understand and resolve complex issues (Resnick & Wilensky, 1998); (e) learn within their cultures (Banks, et al., 2007); (f) learn how to resolve problems (Hmelo-Silver, Marathe & Liu, 2007), and; (g) learn how to collaborate with each other (O'Donnell, Hmelo-Silver & Erkens, 2013) to build a sustainable and resilient future.

In this symposium we bring together scholars studying some of the aforementioned aspects of educational practice across a diverse set of learning environments in addressing the question of how we in the learning sciences can contribute to this “different kind of education” (Orr, 1992). The symposium includes discussion of a variety of challenging issues faced by youth and adults, students and teachers as they address sustainability and resilience in local and personal, as well as globalized contexts by researchers from different disciplines within the learning sciences community.

Our exemplars are geographically and culturally diverse. By profiling how youth in Bhutan merge formal and informal value systems to engage environmental decision-making processes, the symposium not only invites conversation about how youth in Bhutan learn to engage with complexity but also how they merge formal and informal knowledge so as to learn environmental problem solving strategies that lead to sustainability. As a part of the symposium we discuss how rural communities in Ghana and Tanzania use an anticipatory learning framing to learn about processes that would help them plan for the future changes occurring due to the impact of climate change. In this presentation we also discuss the importance of connecting the past and the future to the present lives of Native American students. Finally, the symposium includes a project that discusses the challenges faced by teachers in the United States while teaching climate change in the formal classroom.

## **Learning to Make Decisions in the Bhutanese Himalayas**

Sameer Honwad, New York University

Learning to make decisions in everyday life that lead to environmental sustainability will allow communities to better cope with current impacts and shape future ones (Smit et al., 1999). Literature in environmental adaptation suggests that environmental decision-making that would help mitigate the impact of climate change and help communities adapt to the changing environment requires that individuals: (a) learn that everyday actions (eating breakfast, using technology, washing clothes, etc.) are interactions with the environment; (b) understand that everyday actions/decisions have an impact on the environment at a local, national and international level, and; (c) understand that the long-term impact of these actions/decisions is an important aspect of how one can adapt to the changing environment (Bhagwat et al., 2005).

Using the three points mentioned above, this study examines the current status of how youth in the Bhutan Himalayas understand the environmental decision-making process. The study focuses on the Bhutan Himalayas, communities in the mountain regions of Asia that are highly vulnerable to the negative impacts of the climate change and therefore are in an urgent need to understand and learn to adapt to the changing environment. The retreat of the Himalayan glaciers threatens Bhutanese populations by decreasing their access to water supplies and dramatically changing the landscape that they rely upon for subsistence (Anthwal et al., 2006). The retreating glaciers also pose a threat to the Bhutanese economy, as their main income generator is hydro-electricity. Given the urgent need to help the people in Bhutan to adapt to the changing environment, this study focuses on how to help youth in Bhutan understand the process of decision-making that would lead to greater environmental sustainability.

The study examines the process of environmental decision-making through the lens of education/learning and comments on the improvements required in formal environmental sciences/education curriculum so that young people can reflect on the decision-making processes, understand how to mitigate the impact of climate change, and adapt to the changing environment. The study addresses five research questions: 1. What are the main activities that occur in the everyday lives of college students in Bhutan? 2. How do the youth in Bhutan conceptualize their everyday life decisions in terms of the impact on their local environment? 3.

How do Bhutanese youth understand the impact of their everyday life decisions on the environment beyond local level—at national and international levels? 4. How do Bhutanese youth conceptualize the long-term impacts of their everyday life actions/decisions? 5. What role does the formal environmental sciences/education curriculum play in the everyday life decision-making processes among the youth in Bhutan?

The study seeks to address the deficiency in the literature for environmental decision-making processes from a learning and education perspective. The goal of the study is to help youth understand that everyday life decisions involve environmental interactions and that in order to be good stewards of the environment the focus needs to be on reflecting on everyday life decisions. The study also seeks to move beyond the current paradigm of environmental education, which discusses good decisions (recycling, riding a bicycle, buying organic food, etc.) and bad decisions (driving a non-fuel efficient car, not buying local, eating meat, etc.) in terms of having an impact on the environment. The study keyed on two questions: how do people live their everyday lives? and, how can we make our future generations aware of good problem solving skills that would lead to sustainability? As Sillitoe (2007) emphasizes, there is a need to engage the complexity that characterizes people's everyday lives and the relationships that they share with their place. Thus, the study is designed to take the first step so as to understand how people live their everyday lives and how they understand the impact of their lives on the environment.

The study used ethnographic methods—participant observations and interviews—to answer the research questions. Twenty-two first year college students participated in the study. The main finding of the study was that students do not view their everyday life actions/decisions as a part of interaction with the environment. While more than 50% of students understood that their food-, technology-, and transportation-related decisions had impact on the environment, only 1 student understood that recreational activities/decisions also have an impact on the environment. It was observed that students struggled with thinking about their everyday life actions having impact at a broader scale. While a majority of the students understood that there could be some impact at the broader scale, they exhibited a poor understanding of the impact itself. This can be observed through examining the answers of why might there be an impact at the global scale. For example, when asked whether their food habits would have an impact at a broader scale, a majority of respondents talked about wasting food as the only impact that would happen at the broader scale. While food wastage is definitely a global problem, there are several other problems such as mass production of agriculture or import/export of food that were missed. Thus, overall the students were not able to display an understanding of interconnectedness. The idea of interconnectedness is an important concept in the learning to adapt and build resilience conversation. Interconnectedness helps students understand how environmental decisions are tied into one another and impact local and global environmental systems.

The students also displayed an idea that there are 'good' and 'bad' environmental practices. When discussing impacts, the students only discussed those that were considered negative. Even when told that they should talk about both negative and positive impacts the students only discussed negative impacts. This is a perspective that is often observed in environmental education programs. The idea that there are good practices and bad practices is not always conducive to advancing the sustainability discourse. Other research also indicates that environmental education research aimed at adaptation and resilience building should move away from imparting to the students knowledge about 'good' decisions and 'bad' decisions (Tilbury, 1995).

Student respondents did not see their environmental sciences curriculum as a part of their everyday life. Even though they discussed getting their information from the environmental sciences curriculum, they were not able to connect the information in the curriculum to their everyday lives and thus are not able to understand the interconnectedness among the environmental phenomena and lives of people all over the world. The curriculum itself takes on a broad view of the environment. While the authors try to connect the curriculum to the everyday lives of the students, it is observed that the curriculum does not succeed in connecting the content to the students' everyday lives. Also, the curriculum is further isolating to the students of Bhutan as the authors have a universal/Western science viewpoint.

The main findings above suggest a different approach to designing an environmental sciences curriculum for the students of Bhutan to help them adapt to the changing environment. An environmental sciences curriculum that focuses on adaptation to climate change needs to address the element of interconnectedness. Interconnectedness requires the students to understand how local systems and global systems are connected to each other and also have the students think about their decisions in terms of future impacts. Learning about the environment would require learners to think about the known (local-short term) and the unknown (global-long term). The learners also need to understand that even the smallest of the actions/decisions in their everyday lives create a disturbance/adjustment in the environment. To deal with a problem of such dynamic nature requires constant dialogue (deliberation/mitigation) and collaboration (sharing of knowledge). It will require equity, as collaboration studies have observed that any collaboration between non-equal partners is not successful. Thus, any design for environmental science education in the future should put the above-mentioned elements in the center and the content matter as support material. Every chapter/lesson in

the curriculum should be outlined as local and global, short-term and long-term, and should have an emphasis on mitigation, collaboration, and consensus building.

## **Resilience Through Relationships: Utilizing the Past to Build a Better Future**

Rose Honey, Harvard University

Adaptation and resilience building includes an understanding of the past to build a sustainable present and future (Smit et al., 1999). This presentation examines a curriculum development process that incorporates the past, present and future with the intention of helping Native American students to adapt to their changing environments while learning about their traditional culture and the world around them. Research suggests that for Indigenous children who live in traditional communities, incorporating cultural relevance into science lessons can help students to negotiate their life-world culture into the culture of school science (Aikenhead & Jegede, 1999). It also promotes student intrinsic motivation to learn about the environment around them (Honey, 2013). Spotlighting the development of a curriculum that is developed for Native American communities as they move through western/modern and traditional cultures demonstrates how to combine Native learning processes such as relationship building, respect for the environment, and interconnectedness with scientific experimentation and concepts. As the TIMSI model explored by Estrada (2011) suggests, this curriculum encourages teachers and students in early learning classrooms to think about the water in their community from both a cultural and Western Modern scientific perspective, thus hoping to promote deeper integration and “durable motivation to persist as a scientist.”

Discovering Our Relationship with Water is an early learning science curriculum being developed as part of The Handbook on Designing Curriculum Honoring Tribal Legacies: An Epic Journey of Healing. This multi-literacies handbook, supported by the National Park Service, revisits the history of Lewis and Clark and the Corps of Discovery and integrates culture and Indigenous perspectives into curriculum units that focus on a variety of learning disciplines (Honoring Tribal Legacies, 2013). One important goal of this project is to connect present-day people, including tribal communities, to the places associated with the Lewis and Clark expedition. The Lewis and Clark National Historic Trail provides an opportunity to demonstrate the continuum of human history in these same locations and the subsequent relationships that have developed and will develop with our environment and our culture into future generations. Through the lens of history, young learners will be guided to think about our relationship with water, and what human relationships with water were like during the time of Lewis and Clark. Through future iterations of this curriculum aimed at older learners, students can begin to think about how humans have adapted to changes in our relationship with water today and can then begin to discover what our relationship with water might look like in the future. The ability to learn from the past and transfer these lessons toward problem solving in the future is an important skill in a world where we need to learn to adapt to a changing environment.

Water is fundamental not only to our survival, but to our personal health, to the food that we eat, to industry in our communities, to travel, and almost any activity that we participate in. The relationships that we have with water will determine our lifestyles and possibly our survival into the future. Focused on early childhood education (ages 3–5 years), this curriculum is aligned with Common Core State Standards and Next Generation Science Standards. It aims to guide students to discover and build their own relationship with water, learn how water is connected to their community, and begin to understand the importance of water in our environment. Through these lessons, students will begin to build foundations for thinking about human and other organism’s relationship with water in the future. There are six units or “learning episodes” which incorporate three main elements: Honoring Tribal Legacies, Scientific Experimentation, and Lewis and Clark and the Corps of Discovery. One goal that honors tribal legacies is to have students look at water as a sacred and living entity that takes care of us, and that needs to be taken care of by us as humans. Another component is to guide young learners to explore water through experimentation, and familiarize them with the idea of scientific exploration. And finally, utilizing Lewis and Clark and their quest to find a water passageway to the Pacific Ocean, the curriculum connects details of their journey to lessons about water and relationships with tribal people. Incorporating these elements into each lesson helps guide students to consider the past while predicting and problem solving in the present and for the future. The six learning episodes are:

1. *Connections: The Water in Our Community.* This episode focuses on how we are connected to the water in our community.
2. *Balance: Sinking and Floating.* This learning episode is focused on balance and the importance of having a balanced relationship with water.
3. *Transformation – Gas, Liquid & Solid.* This episode recognizes that water can transform, and that this can help to keep nature in balance.
4. *Cycles – The Movement of Water.* This episode teaches that water moves from place to place as part of the water cycle.

5. *Reciprocity – Happy & Healthy Water.* The focus for this unit is on how we can take care of water and how water takes care of us.
6. *Relationships – Plants, Animals & Water.* This learning episode teaches learners that we all have a relationship with water.

Thinking about how water looks, feels, and sounds, envisioning boats floating or sinking in rivers, imagining water freezing in the winter and thawing in the spring, looking for food in water such as plants and fish—all of these are vehicles toward thinking about our relationship with water and the relationship that water has to many different things in our world. Engaging students at a young age in these teachings will inspire and initiate a journey of play and inquiry that are designed to promote understandings, discoveries, and relationships related not only to water, but also to the world around us. By bringing past events into lessons for the future, teachers can guide students toward a type of learning that helps them to gain a sense of self, feel more connected within their community and with the world around them and fosters a sense of stewardship and relationship building so that at a young age, students begin to build relationships with our environment and learn to take care of everything in the world that we are connected to.

In this presentation, the design process associated with the curriculum will be discussed as well as how stakeholders from various backgrounds and with different agendas help to shape the curriculum aimed at the adaptation process. Additionally, there will be an emphasis on the methods of including affective domains of learning such as engagement and relationship building into an environmental science curriculum. This motivates students to care for their environment as they bridge the gap between formal and informal learning environments, and promotes an understanding of our past as a means toward building a sustainable present and future.

## **Climate Change, Anticipatory Learning, and Co-resilience in Vulnerable Places**

Kenneth Tamminga, Pennsylvania State University

The flurry of climate change and resilience discourses at larger scales of theory and praxis can overlook the tenuous relationships between rural communities and their landscapes. Our interdisciplinary project, Anticipatory Learning for Climate Change Adaptation and Resilience (ALCCAR), was funded through a grant from the National Science Foundation's Human and Social Dynamics Program. It took place in rural Ghana and Tanzania from 2009 to late 2012, and involved a consortium of U.S. and African scholars and non-governmental organizations (NGOs). Disciplines represented on the research team included geography, learning science, landscape architecture, climate science, community development, and disaster management. We explored community-level adaptive capacity using the concept of anticipatory learning, defined as learning about and imaginatively engaging with alternative futures as climate change impacts are increasingly felt. We were interested in how iterative social-ecological learning may enhance a community's capacity to make flexible decisions in the face of growing uncertainty and climate change. We argued that resilience of social-ecological systems relies on iterative learning, reflection, and innovation based on past knowledge ('memory'), present understandings ('monitoring and observation'), and anticipation of future change ('envisioning') (Walker et al., 2004; Tschakert & Dietrich, 2010). This grounded methodology emerged from an interplay between the applied scholarship of investigators and the local sensibilities of co-investigators drawn from regional NGO partners, broadly informed by theory in the learning sciences, management studies, and community planning and development.

We conducted a series of participatory research and learning activities (n=15) in each of the 8 rural communities, and in the context of 3 kinds of relational spaces: *visceral/embodied* (e.g. walking journeys, environmental monitoring), *discursive/dialogic* (e.g. scenario building, local theatre, futures mapping), and *material/diffusive* (e.g., scaled-down climate projection trainings, landscape inventories) (Tschakert, Tamminga, and Dietrich, 2013). We report here on several tools that seem relevant in the context of these proceedings.

The walking journey activity emerged following start-up events that gauged community-scale anticipatory learning capacities through participatory decision-making and information flows. It quickly became apparent that many of these processes were situated spatially through a localized vocabulary of places and pathways. Thus, we worked with our NGO partners in devising walking journeys with select influencers who led us through their daily working environs and special places. The 3 thematic journeys were *Elemental* (water and soil), *Biodiversity* (local and regional flora and fauna), and *Place* (sacred and special places and pathways). Earlier social network mapping and advice from village leaders were used to identify a pair of key informant-guides for each theme. The pair then devised and led a 3–4 hour walk through the landscape surrounding their village, interpreting the history of change, current status, and sustaining capacities along their designated theme. Videotaped data were transcribed and coded, with findings showing a range of place-based awareness. The walks helped us to see how resident experts learn from the land, how they are connected to its past and present, and how they share land-based knowledge. However, levels of expertise, deep understanding of natural process, and extent of knowledge sharing through the village varied largely from one pair of guides to the next. An

unanticipated positive outcome was that reference to the walking journeys as a way of knowing was repeatedly made during later community-wide activities (e.g. community theatre, layered mapping, exit interviews), indicating a collective confirmation of the niche role that place-based influencers could play in building adaptive capacity.

Concurrently, the environmental monitoring activity engaged small groups of resident volunteers in gathering and assessing environmental data. We instructed these citizen scientists in observing and charting local phenomena of relevance to their small-scale farming and fishing economies (e.g. temperature, rainfall, erosion, patterns crop yield and prices). After 12-18 months of data collection, monitoring results provided opportunities for sharing knowledge, and corroborated earlier village-scale instruction on downscaled climate projections led by the team's climate scientist. As one participant noted, the monitors and walking journey guides represented each community's "living library." Post project, and with the ongoing assistance of regional NGOs, monitoring groups continue to collect data and share insights at the village and district levels.

The scenario building activity initiated the final phase of research focusing on the future. Representative groups of women and men developed three distinct visions of their community set in the year 2035, under several possible climate change regimes. Facilitated through our NGO practitioner partners, we introduced information about future precipitation and temperature from downscaled climate projections, injecting trends and surprises beyond the community's embodied knowledge. Participants explored and navigated their values, fears, and dreams for the future. The creative co-learning process resulted, once again, in varied scenarios, from idealistic to realistic to rather gloomy. In Ghana, optimistic scenarios were most frequent; in Tanzania, apprehension and realism were at the fore. Even within village groups, some scenarios revealed contested trajectories. Yet all participants got a taste for the creative power of envisioning uncertain-but-plausible futures, and all were eager to proceed with more detailed conceptualizations.

The layered mapping activity played out a nascent form of community planning and resource management. Facilitated by our NGO partners who we trained in advance, a layered mapping exercise was conducted with participants from across the community. Acetate overlays allowed ideas to be placed over the Community Map paper base that had been constructed during the earlier scenario building. The two overlays, *Concern & Opportunities* and *Ideas for the Future*, addressed the working themes of resource allocation, environmental hazards, infrastructure, civil discourse, and longer-term environmental monitoring. All participants were invited to contribute using dry-erase markers, applying commonly understood symbols as a sort of iconographic shorthand. This was followed by a reflective group-wide discussion that considered the mapping process, its content, degree of inclusivity, and next steps. We found that participants were quite adept at basic concept mapping, and spatially well aware of competing resources and spaces. More significantly, we witnessed almost all participants beginning to grasp the sense of empowerment that could come from even this sort of rudimentary 'proto-planning' as a creative and negotiated endeavor. However, idealism consistently outweighed realism in all 8 communities; setting attainable, flexible and complementary goals remains a subsequent step to tackle.

Community leaders are now working with our NGO partners in refining and scaling up planning options in anticipation of climate change impacts and opportunities. Grounded anticipatory learning and participatory envisioning of preferred-but-realistic futures is just a part of the complex challenge of building local capacity to achieve co-resilience: communities and working landscapes that each sustains the other through time.

## **Learning to Research: Fostering Climate Change Education Through Student Climate Research**

Ofelia Mangen Sypher, Christopher Hoadley and Armanda Lewis, New York University

The "Learning to Research" (L2R) project was a three-year experiment in fostering climate change education through student-led inquiry oriented climate research conducted in the context of the GLOBE program ([globe.gov](http://globe.gov)). Normally, GLOBE uses scientist- and educational researcher-developed curriculum to involve students worldwide in earth science data collection, aggregation, and to some extent analysis. Dissemination is carried out primarily through teacher training on pre-developed data collection protocols, teacher and student conferences, and through online sharing of data. L2R took a different approach in which teachers were asked to create student- or teacher-led inquiry science curriculum on climate change, using either existing data or data they would collect. In this novel teacher professional development model, teachers were given face-to-face professional development (3 days in-person per cohort), and then were supported to connect with professional scientists, GLOBE educators, and each other online to design their own curriculum. They also participated in monthly seminars on Adobe Connect in which shared project-related issues and solution, as well as heard career-oriented presentations by professionals using climate-related STEM knowledge in a wide range of careers (from scientists to disaster relief and public health professionals).

In this symposium, we discuss two sets of findings from the project. First, we present the results of a study of collaboration processes on the curriculum design teams. This study examined collaborative outcomes using the TACIT framework (Hoadley, Lee, & Sockman, 2006) based on five dimensions of collaborative challenges: Trust, Awareness, Contextualization, Incentives, and Techniques for Coordinating. Results indicate that these dimensions of the collaboration did help predict success on designing and implementing climate change curriculum. Of the surveyed participants, those who reported that they successfully completed their projects also had higher mean TACIT scores than those who reported that their teams were “partially successful at achieving goals” ( $p=.999$ ). We speculate on ways these dimensions might have been influenced by the project design, the collaboration factors (group type, communication media, co-location, etc.).

Secondly, we discuss cases that explore how climate change teachers perceive of their participation in technologically enhanced, collaboratively based professional development activities with respect to educational and research objectives. Such markers of successful L2R integration, which were triangulated with survey data, include the degree to which teachers access expert knowledge, report changes in their own or their students’ disciplinary knowledge, and observe instances of student-led use of data to explore climate-related issues. Additionally, we will illustrate the unanticipated difficulties in helping teachers address climate change in their classrooms, and how these unanticipated difficulties were addressed in successive cohorts in the teacher training. These unanticipated difficulties included: participating teachers’ misconceptions about the fundamental processes of climate change; the need to have strategies for addressing the politics of teaching climate change; challenges surrounding collaborative project-based learning; and the difficulty of having students generate answerable questions about climate through data-driven inquiry. Changes in the program for later cohorts included: increased training on basic climate science; a reduced reliance on distant teacher-peers as co-implementers of geographically distributed curriculum and increased reliance on them as advisers and/or sources of case data; more emphasis on regular, technology mediated check-ins with the whole group; and additional mentorship on the development of specific research questions and collaborating with local scientific experts.

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# **Learning Across Settings: Towards Transformative Trajectories of Practice**

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**Abstract:** This symposium brings together examples of movement across space, time and context to understand the details of building educational settings that allow for participants to create connections and grapple with the contradictions that arise as they move across settings. These analyses are examples of how students appropriate tools and make connections to assemble valued trajectories of learning. Moreover the cases provide insight into how researchers and practitioners can expand their focus on learning to include the connections and possible coordination across educational experiences in various contexts: school, afterschool programs, home, museums, and community spaces. A focus on cross setting learning recognizes all of these places as rich learning environments with their own histories and cultural practices. We are ultimately interested in how people make sense of and draw connections across settings in order to enhance the possibilities for equity oriented and transformative learning.

## **General Introduction**

Learning scientists are increasingly concerned with the ecologies of learning—the distributed network of histories, locations, relationships, and artifacts—that people work with as they appropriate new tools and practices (Engeström, 1987; Nespor, 1994; Gutierrez et al., 2010; Leander, K. M., Phillips, N. C., Taylor, K. H., 2010; Rahm, 2012). Attention to learning as a distributed process that happens across settings and over time has implications for how we study learning, design expansive learning environments, and support the development of educators (Jurow, 2005; Hall, R., Wright, K. & Wieckert, K., 2007). Researchers, program designers, and teachers are positioned to attend to sense-making practices as they extend beyond the artificially bounded space-time continuum of the single setting or activity. Yet, as our attention turns to cross-setting learning, we need a multiplicity of cases and examples that help illustrate what this learning looks like in practice. Deepening our understandings of what takes hold as people move within and across settings (Street, 1995; Vossoughi & Gutierrez, in press) also demands a shift in focus from the individual and the singular environment to the multiple environments and the constellation of tools and relationships that arise in and across settings.

To this end, the proposed symposium asks: How do ideas, tools and practices travel across settings? How might fine-grained analysis of such movement help illuminate the dynamics of appropriation as a form of deep learning? More broadly: what are the methodological and pedagogical implications of attending to learning across settings? We argue throughout that tracing the appropriation of tools and practices across settings is essential for studying learning in ways that connect micro-genetic, onto-genetic and socio-cultural change (Hall, R. & Horne, L., 2012). As Rogoff (1998) argues, appropriation involves shifts in participation that contribute to and help transform the environment or practice itself. Moreover, a focus on cross-setting learning can push the field to better understand both the interdependence and potential disjuncture of identities and learning experiences across multiple locations of participation.

Designs for learning environments are informed by our understanding of what robust learning is and how it is cultivated. Accordingly, understanding how tools and practices move (or do not move) across settings offers new insights for organizing learning environments within local communities as connected to larger social, political and historical spheres of activity (Nespor, 1994; Lave, 2012). For example, supporting the kinds of learning experiences where students are actively constructing meaning and knowledge within the context of their everyday lived experiences requires researchers and practitioners alike to take seriously the multiple places and practices that students draw upon to make new ideas, dispositions, and skills meaningful. As a number of scholars have argued, the pedagogical leveraging of everyday experience is all the more pressing for youth whose home and community lives are treated as deficits to be overcome rather than resources to draw upon (Gonzalez, et. al., 2005; Gutiérrez & Rogoff, 2003). Similarly, Rahm (2012) argues that ‘while single space-based research of informal learning is important, it rarely questions the role of such learning in a larger network of practices and within a web of practices differentiated by power.’ From this vantage point, the institutional and pedagogical conditions that support learning across settings have the potential to disrupt and transform larger

social hierarchies. We argue that the learning sciences would benefit from a closer examination of how these appropriations become significant and incorporated across place.

Collectively, the three papers in this symposium will focus on learning in hybrid spaces that seek to connect practices across settings and explicitly organize for transformative possibilities. Specifically, the authors trace tools and practices as they travel and contribute to the development of hybrid spaces (Soja, 1989; Gutiérrez, 2008). Vossoughi, Escudé and Kong explore pedagogical practices that make explicit connections between after-school, home and school to encourage appropriation. Mendoza traces how pedagogical tools serve multiple functions across a social design experiment and work to create multiple layers of learning and identity and utilize contradictions as a source of learning. Shea follows graduate students through a distributed network of business school activists to see how the group appropriated tools and repurposed them in their attempts to disrupt local circumstances.

All of our papers share a methodological focus on appropriating tools across settings and a sensibility that involves asking: who gets to introduce tools within hybrid spaces? For what purposes? In his role as discussant, Manuel Espinoza (University of Colorado at Denver) will use his expertise in studying the moment-to-moment transformation of educational spaces through language, tools, and narrative to provide insight and critical feedback with regards to the development of pedagogical design and imagination. His work on “educational sanctuary” is particularly relevant to our focus on hybrid spaces.

## **Tinkering and Appropriation: The Pedagogical and Equity Implications of Learning Across Settings**

Shirin Vossoughi, Meg Escudé, Fan Kong

This paper looks closely at the role of cross setting learning in an after-school program organized around tinkering and making. This program is partnership between a science museum and two local Boys and Girls Clubs, which work to develop and implement a sustained tinkering curriculum focused on interdisciplinary and artful forms of STEM learning. In line with the philosophies of the Boys and Girls Clubs, learning is also grounded in youth development and play. Adults, teens and children meet in a workshop setting to design and co-create artifacts such as scribbling machines, stop-motion animation films, shadow plays, wooden pinball machines and musical instruments.

From its inception, this project has been driven by equity-oriented goals. The after-school program predominantly serves immigrant and diasporic youth from communities with restricted access to educational and economic opportunities. Rather than defining equity (only) as the broadening of access to high-quality STEM education, we have been working to study the pedagogical “how” of equity in a tinkering context: the moment to moment practices that help build an inclusive, challenging and intellectually respectful learning environment for all participants (Vossoughi, et. al., 2013). In studying and defining some of the design principles that constitute equity-oriented practice, we have identified “connections across settings” as a core value.

This paper draws on ethnographic data collected over the last year and a half to examine and illustrate the multiple meanings of cross setting learning in a tinkering context (Erickson, 1986). This ethnographic data includes: field notes, audio-video recordings of both whole group and small group tinkering activity, photographs of students artifacts over time, and interviews with children, parents and educators. In particular, this presentation looks closely at moments that have been coded as illustrating cross setting learning, such as: specific moves made by educators to draw on and leverage children’s repertoires of practice (Gutiérrez & Rogoff, 2003), moments within the program when participants make connections to experiences and artifacts from home, school and other spaces outside the after-school setting, and moments when ideas, tools and practices “travel” from the tinkering setting to other contexts. In this vein, we have been studying the process of appropriation both in terms of how children draw tools/practices from other parts of their lives *into* the tinkering setting and how they draw on the tools/practices developed in the tinkering setting to approach problems encountered outside the setting in new ways, or to extend their making/tinkering practice beyond the time-space of the after-school program. We are interested in better understanding how these moments reflect and constitute deep forms of learning – i.e. what they signify in terms of children’s shifting participation in and relationship with science-rich tinkering practices (Nasir, et. al, 2006).

We argue that designing and organizing learning in ways that cultivate connections across settings supports equity-oriented goals by widening definitions of learning, intelligence and science, recognizing and leveraging children’s strengths, and drawing meaningful connections between the scientific and the everyday (Gonzalez, et. al., 2005; Vygotsky, 1986). We also address possible tensions that emerge in this work: such as the powerful role dominant definitions of “science” play in enabling or constraining cross-setting learning, and the potential disjuncture between learning in a setting that feels like “play” and carrying those experiences over into settings that feel like “school” (and vice versa). Here, we include a discussion of the kinds of reflection and openness involved - among children, educators and researchers - in allowing the settings themselves (school, home, after-school) to learn from one another. We conclude with reflections on the specific methodological

practices that help make the dynamics of cross setting learning visible, available for interpretation and useful for the continuous process of design and pedagogy (Vossoughi & Gutiérrez, in press).

Finally, in line with collaborative action research (Erickson, 2006) and social design experiments (Gutiérrez & Vossoughi, 2010), our research is deeply embedded in program design and implementation. Researchers and educators collaboratively design pedagogical environments and reflect on the kinds of shifts that emerge among participants in the after-school settings. In practice, this process of co-design involves educators serving as contributing members of the research team, and researchers participating as co-designers of curriculum and pedagogy. The director and lead educator of the After-School Tinkering Program (co-author on this paper) therefore played a central role in co-designing research questions, observational and interview protocols, codes and analyses, and serves as one of the authors on this paper.

## **Mediated Boundary Crossing: Traveling with Pedagogical Artifacts across Space**

Elizabeth Mendoza

In an effort to address the enduring and pervasive division between theory and practice, this paper examines the way tools, or pedagogical artifacts, move across multiple settings to foster praxis, theoretical cohesion across settings and multiple layers of learning for undergraduate and graduate students. Through the documentation and analysis of a social design experiment—which seeks to create and study change and work toward praxis with an aim of promoting equitable practices for non-dominant students (Gutierrez & Vossoughi, 2010)—this study traced tools across multiple spaces to provide insight to their potential of becoming multi-faceted.

With the notion of movement as learning (Gutiérrez, 2008), *theory* is utilized to create robust teaching and learning spaces and *practice* is used to more deeply understand theory. Of import, this praxis does not happen spontaneously or through movement alone (Engeström 2001, Engeström & Sannino, 2009). It necessitates intentionally designing pedagogical tools that move across each unique space, - a process of mediated boundary crossing.

I draw on data from El Pueblo Mágico, a social design experiment, that engages undergraduate students through pre-service teacher course, elementary students through an associated elementary school practicum site and a larger research/instructional team comprised of graduate students and faculty. For this paper, I analyze audio data from the instructional team and video and class assignments from the undergraduate course. With particular attention to the learning process of the instructional team and undergraduate students, I detail the tools utilized across spaces and analyze the shift in the role of the tool, or learning artifact, depending on the space it occupies. Specifically, I follow the weekly response to reading assignment and Cognitive Ethnographies—undergraduate practicum site field notes—through the multiple settings including: instructional team meetings, individual writing processes and whole group class discussions. By tracing pedagogical tools in this way, I demonstrate how each pedagogical tool was utilized uniquely, yet consistently, in each setting to deepen the understanding of theory and practice for all involved participants. Through the examples, I demonstrate the way common sense notions (Gramsci, 1999) of learning and teaching shift for undergraduates and deepened for graduate students. In particular, I focus on the ways these pedagogical tools work to promote reflective practices that start to highlight the ways our everyday, moment-to-moment actions are an extension of our larger societal common sense notions and the tensions that arise when these common sense notions are challenged by more robust theoretical understandings learning and teaching. The contribution of this paper is to demonstrate the way that the mediating pedagogical tools have potential to promote cohesion across learning ecologies and create multiple layers of learning across spaces.

## **Organizing Business for Social and Environmental Sustainability: Learning in an Emerging Field of Practice**

Molly Shea

“As part of changing our activity in changing circumstances, we need to consider the most politically critical sites of political change, that is we need to make familiar and recognizable our own everyday possibilities for ‘revolutionary praxis’ and take them up in our research practices” (Lave, 2012).

A growing number of thinkers have posed a challenge to the field of education researchers to consider methodological and theoretical ways to study the processes by which persons are produced and produce themselves in historical and political terms (Drier, 2008; Holland, 2008; Lave, 2012; Rahm, 2012). I studied a group of students within a graduate school of business working to develop and re-form business expertise. In this context, students brought examples and arguments from other contexts—from conference talks to triple

bottom line businesses—to change local business curriculum and entice the broader business community to revise or reimagine business practices. Studying learning as a means of reassembling the world for reimagined social futures requires attention to collective activities that draw on ideas from multiple locations to expand the vision of learning in local settings. I foreground a group of graduate students as they move across settings to better understand the work to reassemble political economies of knowledge in local settings.

There is an expanding network of young people interested in reorganizing business to account for the social and environmental affects of doing business within society. However these students enter business schools largely focused on business practices narrowly defined by generating profits in isolation from larger social issues. This multi-sited, human-centered ethnography explored how a group of business school students leveraged a larger social movement of business activists learning to reassemble knowledge and change accepted business practices in an attempt to “occupy wall street from within”. Carl, Virginia, and Emma were 3 of the 38 students from the local business school who joined an international organization, Net Impact, focused on changing the business model. They all attended the annual NI conference, engaged with NI ideas, events, and activities in the local business school setting, and co-developed a small innovation that became an organizing idea framing local activism work.

The study intentionally focused on student activity outside of formal classrooms. Rather than a more traditional study of education that privileges learning and activity in one setting, I follow students across settings as they interrogate the assumptions associated with the status quo curriculum of the classroom. The students leveraged a powerful network of reformers and activists from around the world to begin to disrupt commonly held practices within the discipline of business. By reaching beyond the local context, students appropriated new tools from distant places as a way to introduce new arguments and practices into their school. Movement across settings introduced new tools into the local context and these examples from distant places became fundamental to the collective activity of challenging a valued knowledge base and corresponding curricular norms within business. When the world and your local context does not look the way you would like it to, you have to draw on other places. Learning as “praxis” involves grasping for examples from history, aspirational speeches about the future, or other spaces to reassemble alternative visions for valued social futures. The sense making practices involved in appropriating tools as people move across place are an important mechanism for understanding learning as organizing for new forms of learning and identity trajectories. The vision of what is possible as groups struggle to assemble new ways of practicing within contentious spaces relies heavily on appropriated new tools from other places.

The study privileges movement through a network to explore how people learn to innovate in complex and contentious spaces where established practices are difficult to disrupt. The flows of material resources, ideas, and practices routed through the network comprising people, things, and ideas brought new connections into spaces to reimagine local places and practices. The network of sustainable business facilitated the movement of ideas and tools such that people could use them to question current practices in the local setting. This paper explored a small innovation that emerged through movement across space and was collectively appropriated in the local setting to reimagine business practices.

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# **Posters**



# **What Do They Do?: Tracing Students' Patterns of Interactions within a Game-Based Intelligent Tutoring System**

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**Abstract:** The authors examine patterns of interactions within the game-based intelligent tutoring system, iSTART-ME. Forty high school students from a mid-south urban environment interacted with iSTART-ME across eight training sessions. Transitional probabilities were calculated based on students' system interaction patterns, focusing on four types of game-based features: generative practice, identification mini-games, personalizable features, and achievement screens. The results revealed how students transitioned from one type of interaction to another and how those interaction patterns varied as a function of the most recent action performed.

## **Introduction**

Recently, educational designers and researchers have investigated the implementation of game-based features into adaptive learning environments (Jackson & McNamara, 2013). This work has provided valuable insight into how game-based features can influence student engagement and learning. However, despite the rapid expansion of this research, relatively little work has been conducted to investigate the patterns of choices that manifest while students interact with game-based systems. The current study aims to gain a deeper understanding of these emergent patterns by examining students' interactions with various game-based features across multiple sessions within iSTART-ME (i.e., Interactive Strategy Training for Active Reading and Thinking – Motivationally Enhanced).

## **iSTART-ME**

iSTART-ME (Interactive Strategy Training for Active Reading and Thinking - Motivationally Enhanced) is an intelligent tutoring system that utilizes embedded game-based practice. This game-based environment has been shown to be effective at teaching students how to use self-explanation strategies to improve their reading comprehension (Jackson & McNamara, 2013). Within this system, students can choose to interact with various game-based features. Some of the available options include: customizing the interface, generating their own self-explanations and playing educational mini-games (Snow, Likens, Jackson, & McNamara, 2013).

## **Current Study**

Students have previously reported that they enjoyed interacting with the iSTART-ME system and its corresponding components (Snow, Jackson, Varner, & McNamara, 2013). However, one area of research that has not been investigated is *how* students chose to interact with the various types of game-based features embedded within the system interface. The aim of the current study is to investigate the nuanced interaction patterns that are formed through students' engagement with the various game-based components embedded within iSTART-ME.

## **Method**

### **Participants**

40 students (50% male, mean grade level of 10, mean age of 15.5 years; 17% were Caucasian, 73% were African-American, and 10% reported other nationalities) interacted with iSTART-ME as part of an 11-session study. Students' interactions within the iSTART-ME system were logged and recorded throughout their time in training. Every interaction in which students engaged involved one of four types of game-based features: generative practice games, identification mini-games, personalizable features, and achievement screens.

### **Quantitative Method**

The current study utilized time-stamped log data to chronologically categorize each student's interaction choices across the multiple training sessions (2 through 9). The sum of all interactions for the 40 students resulted in over 11,000 interaction choices. A statistical sequencing procedure, detailed within D'Mello, Taylor, and Graesser (2007),  $P(X_{t+1} | I_t)$ , utilized this extensive logging database to calculate the conditional probability of a student's action when provided with the previous action.

## Results

In the current study, we examined the patterns that emerge while students engaged with a game-based system. Using the statistical sequencing procedure previously described, we investigated the manifestation of students' choice patterns across time and how those selections varied as a function of students' most recent selection.

### Probability of Interactions

We examined the state transition likelihoods between (and within) features (see Figure 1 for complete set of transition probabilities). Figure 1 provides a visual display of the transition likelihoods, with numbers inside a box representing the likelihood of selecting the same feature again, and numbers near a line indicating the likelihood of transitioning from one feature to another. Summing the probabilities on the left side of Figure 1, approximately 74% of all interactions occurred within a loop between the mini-games and generative practice environments. These interactions consisted of staying within or transitioning between the mini-games and generative practice environments (i.e., 74% constitutes the sum of all transition values within and between the two boxes). This result reveals a practice interaction loop, where students most often sought some form of strategy practice and occasionally alternated between the two different types. This analysis also demonstrates that, compared to the practice features, students were less likely to interact with non-practice features in the environment (i.e., personalizable features and achievement screens).

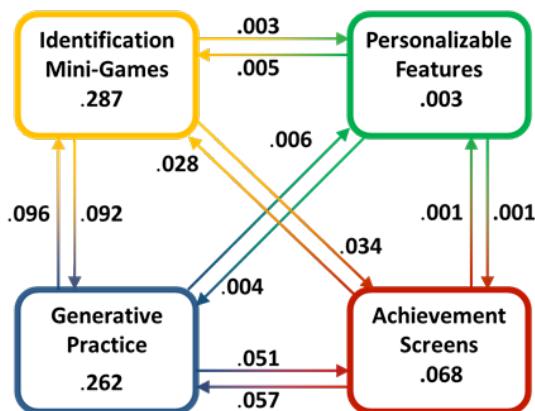


Figure 1. Overall probabilities of interactions (sum of all transitions equals 1).

## Discussion

The analyses presented in the current work are one of the first to categorize and trace users' patterns of choices within an adaptive system. The initial results presented here provide valuable insight into *how* users choose to interact with various game-based features. In addition, this innovative method for assessing users' choice patterns may afford learning scientists the opportunity to better understand learners' behaviors over time. However, future work is needed to examine how these patterns may vary as a function of individual differences and evolve over longer periods of interaction. Understanding the way in which students choose to engage within adaptive systems will afford researchers the opportunity to improve the design and adaptability of game-based educational systems.

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# Implementation Model for Developing Training Measures to Foster Values in an Organization

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**Abstract:** This paper presents an implementation model for developing training measures to foster values in cooperative banks. In this context the present work shows the requirements analysis, conception and realization. The empirical part of this project demonstrates that values have to be concrete and related to practical work-oriented situations to support specific training needs. The developmental part demonstrates how work-oriented training measures on values can be tailored to training needs by drawing on authentic cases.

## Objective and Purpose

Values are a major component of an organization's culture (Schein, 2010) and have increasingly gained recognition as important factors for organizational success in recent years. However, there are deficits in the value orientation of managers and employees. Therefore the goal of the present study is to implement work-oriented training measures to foster values in organizations in the financial sector.

## Theoretical framework

Approaches to foster values can be traced back as early as Kohlberg's theory of moral development (Kohlberg & Turiel 1971). As cases, enriched with dilemma situations, represent an authentic part of reality, they allow training participants to reflect upon possible solutions in ethical dilemmas (Zumbach & Mandl, 2008). From an educational point of view, we suggest that working with authentic cases including dilemma situations from everyday business are particularly potent for fostering values. To bring value-related training needs into the further education of managers and employees of an organization, an implementation process model based on Winkler & Mandl (2004) is developed. It is depending on the specific requirements of the organization.

Modes of Inquiry. The goal of the present study is to implement work-oriented training measures to foster values in organizations in the financial sector: How can a work-oriented training on values in cooperative banks be implemented?

## Research Design

This paper presents an implementation model for developing training measures to foster values in cooperative banks. In this context the present work shows the requirements analysis, the conception and the realization. Figure 1 provides an overview of the implementation process.

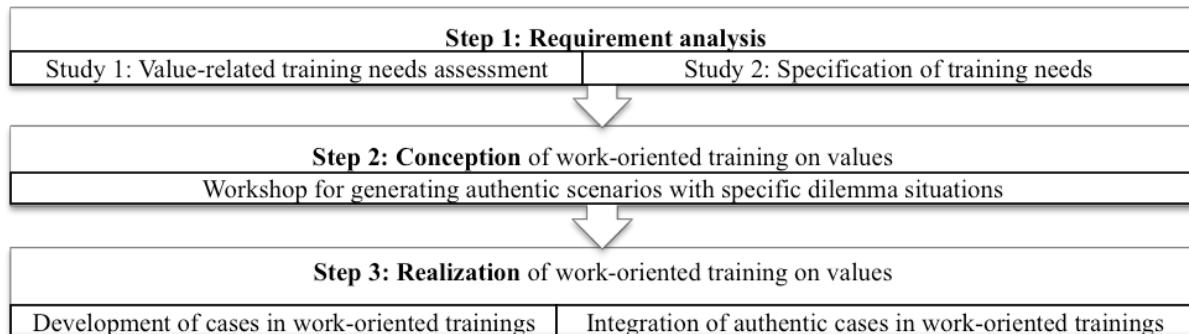


Figure 1. Implementation process

## Step 1: The requirements analysis

The requirements analysis includes two empirical studies which aimed at value-related training needs assessment and the further specification of training needs. The two studies are now presented in this sequence.

### (1) Study 1: Value-related training needs assessment

Questions:

- R1a: How important are the cooperative values for managers and employees from a practical perspective?
- R1b: What is the current contribution of existing training measures for promoting managers' and employees' value orientation in regard to these cooperative values?

Method: An online survey of a representative sample of 506 employees and 186 managers in 16 cooperative banks was conducted. The questionnaire used a 5-point Likert-scales to measure respondents' agreement with value-related statements.

Results:

R1a: Concerning the importance of values managers and employees rate all of the values.

R1b: More than 20 % of the managers and more than 40 % of the employees could not or would not answer how current training contributes to value-orientation. Interpretation: This indicated that while respondents were quick in agreeing with the relevance of values, it was difficult for them to relate them to training and practice.

(2) *Study 2 Specification of training needs*: To further specify training needs in regard to values, an interview study was conducted to gain more in-depth insight into the actual role of values for practice.

Questions:

R2a: Are managers and employees able to specify values in practical terms?

R2b: Are managers and employees able to illustrate the values' practical relevance by specifying work-oriented examples from their own work experience?

Method: Qualitative interviews with 7 employees and 9 managers from 16 cooperative banks were conducted and analyzed by qualitative content analysis.

Results:

R2a: Most managers and employees could hardly recall specific values in and specify in concrete terms how the values relate to their own work.

R2b: Managers and employees were hardly able to give specific examples or cases of actual work situations.

## **Step 2: The conception**

The conception of work-oriented training on values includes a stakeholder workshop with executives from 4 banks and 7 experts of the banks further education institute. The workshop was conducted to identify values particularly relevant for training. Six values were selected that seemed particularly important for training. For each value, two authentic scenarios including dilemma situation were generated. Each scenario included three elements: Scenarios, relating the value to a situation involving managers and/or employees and/or customers or other external stakeholder; the value-related behaviour in that situation and ways of supporting this behaviour in practice.

## **Step 3: The realization**

The realization of work-oriented training on values focusses on the development of these scenarios into cases with trainers from the banks further education institute suited for training. Drawing on the scenarios authentic cases for work-oriented trainings are developed. To realize the cases a first case as example has been developed, representing the basic structure for the other cases. These cases each describe a dilemma situation from the daily workplace operations of managers and employees. Additionally, each case is enriched with tasks for reflection and discussion. The cases are integrated by trainers from the cooperative further education institute into seminars concerning the 4 areas Retail bank, Corporate bank, Operating range and middle management. 6 cases were integrated in specific seminars, ideally matching the content of the respective seminar area. Finally, an online survey is conducted to find out how the trainers from the cooperative further education institute realize the cases after half a year in realization. The evaluation of the realization shows that the realization is successful.

## **Research/Practical Implications**

The implementation model presented here can serve as an example for a comprehensive procedure to foster values. The empirical part of this project demonstrates that values have to be concrete and related to practical work-oriented situations to support specific training needs. The developmental part demonstrates how work-oriented training measures on values can be tailored to training needs by drawing on authentic cases.

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# **“It’s Not as Bad as Using the Toaster All of the Time”: Trade-offs in a Scratch Game about Energy Use**

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**Abstract:** Young people can represent and understand complex systems by designing games. The work we report is from a Scratch workshop focused on understanding trade-offs associated with energy use in relation to climate change. One participant’s work illustrates the potential for game design to support understanding of complexity and, in particular, the mutually constitutive nature of conceptual understanding and the contextualized activity of game design.

## **Introduction**

Many informal programs, resources, and games are devoted to solving problems related to energy conservation and climate change. However, climate change is hard to learn, particularly understanding its systemic causes and implications. *Agency* is critical to how we develop our initial notions of causality (Carey, 2009). Through early agency-related experiences, we learn that we can have an impact on the world in direct and centralized ways. However, our impacts upon nature are often decentralized – the outcomes of collective actions are emergent (Grotzer, 2012). Being in the role of game designer can provide a powerful context for young people to engage with understanding complex systems in science (Kafai & Ching, 2001).

This paper explores how girls designed games in the visual programming environment, Scratch, to teach others about energy conservation, focusing especially on trade-offs associated with energy conservation. We define girls’ understanding of ‘trade-offs’ as how many places in their lives they make trade-offs, what values are implied when they choose, what alternatives are available, and how to make reasoned decisions. Given this definition, we attempt to capture the mutually constitutive nature of conceptual understanding and contextualized activity (Barab et al., 2010). Because trade-offs are integral to decisions related to conservation, and hence to the impacts of climate change, the concept is key in advancing understanding. Specifically, this study sought to address the question: *What particulars of the workshop learning environment support participant understanding of the human, social and environmental trade-offs associated with energy use?*

## **Methods: Participants, Design and Procedure**

Six girls, aged 11 and 12, participated in a 3-day workshop where they created an initial Scratch sketch on climate change, brainstormed game design ideas, learned about trade-offs, built games, tested peers’ games, and presented to their families. All participants had programming experience ranging from one week to over two years. Researchers as participant-observers led the workshop, using a design research approach, providing just-in-time support related to procedural, conceptual and consequential content (Barab, Gresalfi & Arici, 2009). Data were collected in the form of audio-recorded think-alouds, user tests and presentations, Silverback recordings of game creation, storyboards, notes and photographs. Recordings were transcribed and coded using a grounded theory approach (Glaser & Strauss, 1967).

## **Results**

Of the six participants, Amelia’s story most clearly illustrates how grappling with trade-offs in the context of game design can lead to a deeper understanding of the complexities of energy conservation, as well as an opportunity to realize that understanding in a multi-faceted design. Amelia originally framed the choice her game player would make as a simple one involving saving energy. The consequentiality of trade-offs became evident when Amelia grasped (via another girl’s insight) that trade-offs necessitated “multiple right answers” and took the insight much further as a design challenge. Amelia now understood that conservation requires weighing and prioritizing different outcomes. Equally important, it involved developing additional game moves and a more complex game structure overall. Amelia’s story illustrates the mutually constitutive nature of her conceptual understanding of trade-offs and the contextualized activity of design to incorporate those trade-offs. In this sense, the concept materially transformed Amelia’s design, and grappling with the programming deepened her understanding.

By Day 3, Amelia’s game presented the player with a simple choice related to which appliance (toaster oven, microwave, stove, solar oven) was the most “environmentally friendly” (i.e., used the least amount of energy). Julie, an instructor, asked her to think about trade-offs, and she explicitly restated that the trade-off would be convenience:

Amelia: Um, well I just said the one that's most environmentally friendly. So I think that would be correct. Definitely it's not the most- [Julie: - most convenient -]  
 Amelia: -yeah, way to do it. But it's definitely the best for the environment.  
 Julie: So are you still sharing that information about how long it takes?  
 Amelia: Yeah [...] If you click on the objects it pops up, and it says like, "I will take 2 to 4 hours to cook your toast but I use no energy. And then so like the toaster pops up and it takes 2 minutes but uses a lot more energy. So each of them has it, so like 7 minutes, and then the stove 3 minutes.  
 Julie: [...] Will the player know, thinking about the learning goal for a minute, will they learn about trade-offs or will they just learn about the energy? What will they learn from those times?  
 Amelia: Probably that if something's environmentally friendly, it's not always the most convenient.

Later Amelia was urged to think about energy use choices *in terms* of trade-offs. She did so by explaining that the flower - which she kept as a visual metaphor for environmental health – would indicate score: 'So like if your flower is drooping, it means you did really bad.' Amelia began to think about constructive messages that people can take away from a game about trade-offs. Instead of the 'correct answer/positive message' design she was using before, she began to incorporate trade-offs, some related to time/convenience and some to the health of the environment:

Well, I mean it really, it really depends on how much you use them [a toaster versus a solar oven.] Maybe if you have. I know like I wouldn't do this, but you could if you wanted to. So if you took a solar, if you used a solar oven, and maybe you could get up early in the morning and put your toast in and then go back to sleep - [...] but like if you use the solar oven some of the time, and then the toaster like a little, it's not as bad as using the toaster all of the time.

In the end, Amelia implemented her idea about balancing the trade-offs by incorporating it into a script that provided advice to the player before s/he begins to play the game: 'If you use a toaster some of the time and a solar oven some of the time, you don't have to give up electricity altogether but you could still make a difference...' This suggests that the player can choose to have their cake and eat it too! In constructing player choices among "conditions, actions and outcomes," Amelia "narrativized the to-be-learned content" (Barab et al., 2010, p. 19).

## Conclusions

Amelia demonstrated imagination, persistence and engagement in negotiating both conceptual and procedural content that produced complex game play (Barab, Gresalfi & Arici, 2009). For her, design functioned as inquiry using model building. Game design and model building share the virtues of requiring explicitness and iterative design-analysis-revision, incorporating input and output elements, and involving causality. A critical trade-off that arises in this connection is the learner's fluency with the modeling language and its metaphors. Amelia shows that representation of ideas about a system can be developed so that the focus remains on the system and its hypothesized behaviors, the questions and answers rather than the tool.

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## Acknowledgments

This project was funded by the NSF (DRL-0813434). Opinions, findings and conclusions are those of the authors and do not necessarily reflect those of the NSF. We thank Brian Drayton for comments on a draft, and our Scratch girls.

# Controlling for Statistical Dependencies in CSCL Using General Estimating Equations

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**Abstract:** Statistically analyzing small-group discourse in CSCL requires controlling for statistical dependencies among group members that arise from the fact that group members influence one another's behaviors. Although some researchers in the learning sciences have addressed this problem by using multilevel modeling, that approach requires large group sizes. This poster presents an alternative approach, known as General Estimating Equations (GEE), which is more suitable when small groups such as dyads or triads are analyzed.

## The Problem

Computer-supported collaborative learning (CSCL) by definition involves group tasks and group learning. CSCL research often involves experimental and quasi-experimental research that employs statistical hypothesis testing to draw conclusions about the effectiveness of different instructional designs on students' discursive behaviors. The problem addressed in this poster is that student behaviors are not statistically independent from one another, which violates basic, underlying statistical assumptions of many analytic methods.

By way of illustration, suppose students in a study ( $N = 150$ ) are randomly grouped into triads and asked to engage in a synchronous discussion about some topic. Furthermore, half the triads receive some sort of intervention to improve the quality of the arguments made during CSCL discussion (Weinberger, Stegmann, & Fischer, 2010), such as being given information on group members' prior opinions (Buder & Bodemer, 2008). The other half of the triads do not receive the intervention. The number of counterarguments and rebuttals generated in the discussions is found to be higher in the first condition than in the second, but is the difference statistically significant?

A *t*-test could be performed, using the formula for the standard error:  $\text{Sqrt}(2\sigma^2/N)$ . What in this case is the effective  $N$ ? It cannot be all 150 students, because there are not 150 statistically independent data points; the members of each triad affect one another. If one student offers a counterargument, her partner might do so as well for purposes of refutation. Furthermore, students also often imitate one another's discourse moves (Anderson et al., 2001). As a result, the chance of obtaining relatively more extreme observations increase because one extreme observation begets another. If we treat the observations as statistically independent, we will underestimate this probability, increasing the chance of Type I errors.

On the other hand, we could treat the triads as the unit of analysis, but doing so reduces statistical power, because the effective  $N$  is now only 50 rather than 150. This problem has been typically addressed by using a multilevel model (see Cress, 2008), which fits a separate regression line for each small group. However, Hox (2010) recommends that there should be a minimum of 20 students in each group; otherwise, the regression estimates will not be reliable. Small-groups, such as triads, clearly do not meet the sample size criterion. As a result, researchers must either use multi-level model inappropriately or use groups as the unit of analysis. In this paper, we propose a solution that has rarely been used in CSCL and other learning sciences research. The solution involves a new application of an existing methodology.

## The Proposed Solution: General Estimating Equations (GEE)

The GEE methodology (Hardin & Hilbe, 2003) also attempts to adjust for statistical dependence in clusters of observations but unlike multilevel modeling, does not require the clusters to be large. It therefore is a more useful methodology for analyzing behavior in small groups, as long as there are a sufficient number of clusters.

GEE models statistical dependence by estimating to what degree student behaviors are correlated. For example, to what extent are the number of counterarguments generated by one person in a triad correlated with the number of counterarguments generated by another? Fifty dyads would provide 50 data points. Unlike multilevel modeling, the GEE methodology does not attempt to estimate regression lines for each group.

## Technical Details

The procedure begins by estimating a working correlation matrix. With dyads, only one correlation needs to be estimated, but if there three or more members in a group, a matrix would be estimated. In the case of three members, the working correlation matrix would be:

$$\mathbf{R} = \begin{matrix} & . & p_1 & p_2 & p_3 \\ p_1 & 1 & \rho_1 & \rho_3 \\ p_2 & \rho_1 & 1 & \rho_2 \\ p_3 & \rho_3 & \rho_2 & 1 \end{matrix},$$

where  $p_1$  is person #1,  $p_2$  is person #2, etc. Three correlation parameters would need to be estimated, but we could make a simplifying assumption that all three parameters are equal to one another (this option is known as using an “exchangeable” structure). This is not a mandatory assumption, and one can test which type of correlation matrix (exchangeable, unstructured, etc.) best fits one’s data. One can also assume an autoregressive structure if the statistical dependence is associated with repeated measurements. If there is doubt about which correlational structure is correct, a “robust” standard error can be estimated that is less sensitive to choice of the correlation structure.

The second step is to use one’s statistical model to generate predicted values for each individual ( $i = 1 \dots N$ ) on the dependent variable. From the predicted means one can calculate associated variances based on generalized linear models (for example, in analyzing counts using Poisson regression, the variance equals the mean). If there are three members in each group, a  $3 \times 3$  diagonal variance matrix is generated for each of the  $j$  groups,  $(\mathbf{A}_j)^{1/2}$ , and this matrix is multiplied by the working correlation matrix  $\mathbf{R}$  (and  $(\mathbf{A}_j)^{1/2}$  again) to produce a  $3 \times 3$  variance-covariance matrix,  $\mathbf{V}_j$ . The third step is to calculate a  $p \times p$  variance-covariance matrix, where  $p$  is the number of parameters in the overall regression equation. For example, if there is one predictor, then there would be two parameters (an intercept and slope), and so the variance-covariance parameter matrix would be  $2 \times 2$ . It is calculated using the following formula:  $(\mathbf{Cov})_j = (\mathbf{D}_j' \mathbf{V}_j \mathbf{D}_j)^{-1}$ , where  $\mathbf{D}_j = \mathbf{A}_j \mathbf{X}_j$ . The matrices for the different groups are then summed, and the final matrix used to derive standard errors or to update parameter estimates. Further details and a more detailed example can be found in Nussbaum (in press).

The GEE methodology is currently available in various statistical packages, such as Stata, SAS, MATLAB, and R. It is also currently available in SPSS, but only for time-series data.

## Conclusions

The GEE methodology can be used to control for statistical dependencies among group members when analyzing data for individuals engaged in collaborative learning. The methodology does not require the groups to be large, but there should be a large number of groups (at least 30). This stands in contrast to multilevel modeling, which requires fewer but bigger groups. The GEE methodology is currently underutilized in CSCL and other learning sciences research (but for exception, see Lin et al., 2012). This poster will hopefully raise awareness on the merits of this approach.

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# **Between the Lines: The Role of Curriculum Materials and Teacher Language in Communicating Ideas about Scientific Modeling**

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**Abstract:** This poster examines the extent to which teacher language is supported by innovative curriculum materials to engage students in a degree of authentic science practice, specifically looking at lessons which integrate model-based activities. Our findings describe patterns in teacher language during explicit metamodeling instruction, and also describes the ways in which this language appears to be supported by the science curriculum.

## **Introduction**

Innovative, reform-based curriculum materials, such as the project-based materials used in this study, have been developed which reflect the changing needs of society and mirror the work of scientists by integrating instruction of content with scientific practices. One such practice that has been incorporated into these new curricular materials due to both its central role in science work, and it's more prominent role in new reform documents (e.g., NRC, 2012), is developing and using models to advance questions and explanations and to communicate ideas. We know teachers find it challenging to incorporate model-based instruction into their practice (e.g., Windschitl et al., 2008). What is less clear is, if provided the support of reform-based curriculum materials, of which scientific modeling is an integral aspect, whether teachers have the language around which to engage their students in science learning that mirrors authentic science work. Classroom discourse, specifically, the language teachers use to communicate science content, provides the context through which students formulate their own ideas, and is significant for the meaning it can convey to students not just about science content, but also about the nature of science and science practices (Zeidler & Lederman, 1989). Thus, this analysis examines whether teacher language is supported by innovative curriculum materials to engage students in a degree of authentic science practice, specifically looking at a lesson which integrates a model-based activity.

## **Theoretical Framework**

Framing this study is the idea that science learning consists of participation in practice (Lave, 1991), and teacher language is an important tool for socializing students into science learning (Gee, 2004). The social interaction between students and a more knowledgeable other, such as a teacher, is crucial to the acquisition of scientific meaning, which is communicated by, and derived from, language (Vygotsky, 1976). Evidence of a relationship between teachers' language and the subsequent science conceptualizations of students already exists (Zeidler & Lederman, 1989). Specifically, if teacher discourse includes explicit communication of scientifically accurate concepts, for example, about models, students should be more likely to develop accurate understandings about models.

In a classroom learning environment, the language spoken by the teacher is, in part, influenced by the curriculum which guides instruction, and also provides a context through which to situate students in science learning. The curriculum used in this study articulates a project-based instructional stance and emphasizes investigation of authentic problems and participation in scientific practices, such as constructing and using models. Also included in the materials are explicit opportunities for discourse around the nature of science epistemic practices (e.g., modeling), something teachers rarely exhibit in their instruction (Windschitl et al., 2008a). For example, the curriculum includes explicit text that prompts teachers to discuss models in science, and ask students about their experience with models. A defensible hypothesis, therefore, is that the use of this curriculum will support teachers' more explicit language around model-based instruction. Challenges associated with enactment of project-based curricula have been well-documented (e.g., Blumenfeld et al., 1991), as have the challenges associated with model-based science instruction (e.g., Windschitl et al., 2008b). However, aside from outlining the components of scientific modeling and the characteristics of model-based tasks, the research is largely silent regarding the explicit language that has potential to engage students in authentic model-based inquiry. This study describes ways in which teachers utilize these innovative science curricular materials to situate students, through language, in model-based learning.

## Methods

The primary data for this study include video-recordings of classroom instruction during enactment of a lesson focused on modeling in physical science. These data were gathered from the third year (2012-2013) of a five-year (2010-2015) study designed to examine the efficacy of a reform-oriented middle school science curriculum. Participants consisted of nine sixth-grade science teachers, selected because they exhibited explicit metamodeling instruction in their class. These teachers represented a range of teaching experience, education, and science backgrounds.

Given the social and situated framing of this analysis, and the focus on the construct of teacher language, we employed content analysis to analyze transcripts of teacher language during whole-class discussion. Constant comparative analysis (Glaser & Strauss, 1967), was used to identify language patterns across participants. Findings are presented by the themes that arose during explicit metamodeling instruction.

## Results and Implications

Findings presented on this poster describe patterns in teacher language in science modeling instruction. Some illustrative findings are presented here, with more to be elucidated on the poster. We found evidence that these teachers' explicit metamodeling instruction both was derived from and supported by the curriculum. For example, the lesson text recommends that teachers tell their students, "Some models are simply smaller versions of the real object"; this guidance was taken up by five of the nine teachers in this analysis, who described models as "smaller versions" or "smaller scale" or "scaled down version" of the "real object." Additionally, the text prompts teachers to, "Ask the class if they have ever built a model car or train." Four of the nine teachers took up this instruction and asked, for example, "Has anybody ever built a toy plane or a train out of a model? You've made a model car, model train, model plane, right?" (excerpt 10).

This research has implications for curriculum developers and the writing of educative curriculum materials. While this analysis adds to other research evidence indicating that explicit metamodeling instruction tends to be rare in science classrooms, our findings also suggest that when provided access to appropriate curricular materials, teachers' enactment of explicit metamodeling instruction can be supported. Looking at the content of the curriculum and how the guidance for teachers was taken up during enactment, there is arguably a need for more support for metamodeling in order to help enrich teachers' interactions with students about the nature and purpose of models. Additionally, the metamodeling guidance needs to be more grounded in the context of the specific model used in the lesson. As reform-based science curricula aims to support a more robust understanding of science practices and engage students in science in more meaningful ways, it is important to understand the strengths and limitations of these curriculum materials in supporting teachers' efforts toward these ends.

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## Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant No. 1020407. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

# **Exploring the Role of Theory of Mind and Executive Functions in Preschool Children's Hypothesis Testing and Revision**

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**Abstract:** A major goal of preschool science instruction is to foster children's scientific reasoning skills. This study explores the influence of children's theory of mind and executive function capacities on their ability to engage in hypothesis testing and revision. Results indicate that preschoolers are capable of engaging in basic hypothesis testing and revision on a physical science task, and theory of mind capacities may be related to children's performance. Implications for early science instruction are discussed.

## **Issues Addressed and Potential Significance**

There has been an increased focus on incorporating science instruction in U.S. preschool classrooms. A major goal of early science instruction is to aid preschoolers' development of scientific reasoning skills. Research indicates that young children's ability to test and revise hypotheses may depend on their executive function (EF) capacities (i.e., Gropen, Clark-Ciarelli, Hoisington & Ehrlich, 2011). Further, theory of mind (ToM) abilities may also play a role in scientific thinking (Kuhn & Pearsall, 2000). It is around the age of 4 years that children are able to think about beliefs as distinct from reality, and 3-year-olds are unlikely to reconcile inconsistencies between a preliminary belief and a later observation that falsifies it, while older children show less difficulty doing so (Gopnik & Astington, 1988). Thus, it is possible that EF and ToM capacities underlie young children's abilities to confirm and revise hypotheses. This study examines the relationships among preschool children's EF and ToM capacities and their ability to engage in hypothesis revision, a key scientific practice. Further, as research indicates that preschoolers can revise their originally mistaken scientific beliefs when given opportunities to reflect (i.e., Kloos & Van Ordern, 2005), this study also explores whether the use of an instructional tool to scaffold children's hypothesis testing and revision (by facilitating children's reflection on their scientific investigations) leads to improved performance on scientific reasoning tasks in physical science. We hypothesized that use of the instructional tool would foster more accurate hypothesis revision by supporting children's reflection on the differences between their predictions and observed outcomes, and further, that this tool would be most beneficial for children with lower EF and ToM capacities. This work is significant in that it provides a foundation for creating developmentally-appropriate, early science educational experiences.

## **Methods**

Participants were 36 children (17 female) from a central, NJ public preschool (mean age= 53.6 months; range= 43-65). Children were predominantly middle-class and Caucasian. In a corner of their classroom, children were interviewed individually and were asked questions about the movement of objects on an inclined plane of adjustable height. Children were first pretested using a Dimensional Change Card Sort (DCCS) task and three standard theory of mind tasks. The DCCS task examines children's ability to sort objects based on two different dimensions (color and shape). The theory of mind tasks involve presenting a deceptive item to children (a crayon box that contained Band-Aids) and posing questions about the item. Pretest scores were used to create equivalent groups for the experimental and control conditions, controlling for age and gender across groups.

Materials included an inclined plane, six objects made from TinkerToys, a chart for recording predictions and observations, cards for marking predictions and observations on chart, and blue masking tape. Before the experimental task, children in the experimental condition engaged in a brief training session aimed at familiarizing children with using the prediction and observation charts. Immediately after the training session, children in the experimental condition began the test phase. Phase I involved predicting whether various objects would roll or slide down the inclined plane. For each object, the child made a prediction, recorded the prediction using the chart, tested the object on the inclined plane, verbally stated the observed outcome, and recorded the outcome on the chart. The child was then asked to use the chart to determine whether or not the original hypothesis needed to be revised. The child engaged in this hypothesis testing and possible revision two times consecutively for each of the six objects, presented in random order. Phase II involved the same procedure as Phase I, except children were asked to predict whether each object would pass over a piece of blue tape affixed to the floor approximately 18 inches from the bottom of the inclined plane. Children in the control group engaged in the same manipulations for Phase I and Phase II above, except they did not utilize the chart or image cards to record their predictions or observations. Rather, they were asked to verbally state predictions, observed outcomes, and whether the original prediction needed to be revised.

## Preliminary Findings

Children scored reliably above chance on both the ToM and DCCS tasks. The DCCS mean score was 13.33/14 (1-sample t-test [2-tailed]:  $t=31.793$ ,  $p< .001$ ), and the ToM mean score was 1.86/3 (1-sample t-test [2-tailed]:  $t=2.255$ ,  $p=.03$ ). Under the strict criterion of 3/3 points, 12 children passed the ToM task and 24 did not pass. Scores were near ceiling on the DCCS task. Phase I and Phase II scores were significantly correlated ( $r=.524$ ,  $p=.001$ ). For the remainder of analyses, Phase I and Phase II scores were combined to form a Total Score for each participant out of a possible of 120 points. The combined Total Score was correlated with the ToM scores ( $r=.518$ ,  $p=.002$ ) and with DCCS scores ( $r=.355$ ,  $p=.039$ ).

Children scored reliably above chance on the experimental task, with a mean Total Score of 112.56/120 (1-sample t-test [2-tailed]:  $t=40.258$ ,  $p< .001$ ). Children in the experimental condition performed as well as children in the control condition. The mean Total Score for children in the experimental group was 114/120, and the mean for the control condition was 111.12/120. Performing a median split by age illustrated that children in the older age group (mean= 60 months; range=54-65) scored reliably higher than children in the younger age group (mean= 47.35 months; range= 43-53), regardless of experimental condition. The mean Total Score for the older children was 116/120 and the mean for the younger children was 109.12/120. A one-way analysis of variance indicated that this difference was significant ( $F= 8.534$ ,  $p=.006$ ).

High performance and ceiling effects on the DCCS and the experimental tasks made it difficult to determine whether pretest scores were associated with performance on the experimental tasks. A multiple regression analysis was used to test whether experimental condition, age group, ToM score and DCCS score significantly predicted children's Total Score. The results of the regression indicated that the model significantly predicted Total Score and explained 37.7% of the variance ( $F(4,29)= 4.389$ ,  $p=.007$ ,  $R^2 = .337$ ). ToM score significantly predicted Total Score ( $b =.356$ ,  $p=.041$ ). No other predictors in the model were significant.

The mean Total Score for the 12 children who passed the ToM pretest was 118.5/120; the mean Total Score for the 22 children who did not pass the ToM was 109.32/120. A one-way analysis of variance found that this difference in group means was significant:  $F=16.654$ ,  $p<.001$ . Thus, children who passed the ToM tasks scored reliably higher on the hypothesis testing and revision tasks than children who did not pass the ToM tasks. Among the 12 children who passed the ToM pretest, 7 were in the experimental condition and 5 were in the control condition. The mean Total Score for the 7 children in the experimental condition who passed the ToM pretest was 119.29/120. The mean total score for the 5 children in the control condition who passed the ToM pretest was 117.4/120. Among the 22 children who did not pass the ToM pretest, 10 were in the experimental condition, with a mean Total Score of 110.3, and 12 were in the control condition, with a mean Total Score of 108.5. Thus, although there was a trend for children who utilized the prediction and observation reflection charts to perform better than those who did not use the charts when examining groups based on passing/failing the ToM tasks, small n's result in unreliable differences between these groups.

## Conclusions and Implications

This study illustrates that preschool children are capable of engaging in the key scientific practices of basic hypothesis testing and revision on a physical science task, and these abilities increase with age. Further, although the role of EF capacity on children's hypothesis testing and revision abilities remains unresolved, findings provide evidence that ToM capacities may be related to these scientific skills. More work is needed to determine the role of prediction and observation reflection charts in supporting children's hypothesis revision capacities. Relevant implications for preschool education include that children can benefit from instruction designed to help them develop ToM and EF capabilities, and to apply these capacities to learning in scientific domains. Further, children can benefit from educational experiences that involve hypothesis testing and revision as children explore with objects and materials, as well as those which encourage reflection on scientific observations and investigations. Future work is planned to further explore these questions with a larger sample including younger children as well as participants of diverse cultural and socio-economic backgrounds.

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# **Learning to Survive “Home-Free”: Compulsory Learning and the Politics of Freight-Hopping Mobility**

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**Abstract:** This project utilizes methods of grounded theory to explore and make sense of the learning and identity processes associated with two unaccompanied youths’ freight-hopping practices. The purpose of this poster is to advance the notion of compulsory learning to describe the process through which freight-hoppers recover or expand a sense of agency through deliberate shifts in identity, meaning making, participation, tool use, and problem solving that are themselves birthed in forced survival. I contextualize this argument by discussing the aims and dimensions of compulsory learning that frame the pragmatics of constructing agency.

## **Potential Significance**

*Compulsory learning* is a way to understand *learning on the margins*. This poster argues for the utility of *compulsory learning* as a way to understand (1) how one’s marginal positionality within social, economic, and institutional structures may contribute to a range of objectives toward which learning occurs in an obligatory manner, and (2) how one’s response to such contextually-defined objectives must necessarily involve adaption, creativity, coordination, and resolve. Said differently, *compulsory learning* disrupts and re-specifies normative, self-directed understandings of “interest-driven learning,” and argues for a critical investigation into the ways contexts, structures, and environments may compel the interests which drive forms of learning.

## **Theoretical Framework**

As many scholars have noted, locally-constituted cultural practices, characterized by an array of goal-directed activities, circumscribe learning and identity processes (Cole, 1996; Saxe, 1999; Wenger, 1998). In this vein, I will consider learning and identity processes as occurring within and in relation to the sociocultural mobility practice of freight-hopping (Nasir and Cooks, 2009; Greeno, 2006; Wenger, 1998). Additionally, I refer to a sense of agency as the extent to which one perceives the social environment as responsive to his or her deliberate actions toward some objective (Johnston, 2004; Connell, 1998).

## **Methodological Approach**

Over the span of two months, I conducted ethnographic fieldwork in which I immersed myself in the space-time rounds of two, African American teenagers—known affectionately to each other as Smiles and Bones—who engage themselves in the sociocultural practice of freight-hopping and its less organized but mutually constitutive aspects of street-life. Fieldwork took place within and in several instances across one mid-western city at various locations relevant to participants’ daily activities. In addition, I conducted a series of semi-structured interviews to elicit thoughts, comments, and reflections on participants’ forms of learning related to freight-hopping. Field notes and photographs were collected and subsequently analyzed for emergent themes. Audio recordings were selectively transcribed, and then axial coded and analyzed through constant comparative method (Strauss & Corbin, 1990).

## **Preliminary Findings**

Situated on the margins of social, economic, and institutional life, and faced with direct threats to their physical and psycho-emotional well-being, Smiles and Bones feel themselves compelled to engage in complex, interrelated processes whereby they learn to recover, expand or otherwise maintain their own sense of agency as highly mobile subjects. I define this form learning as *compulsory learning*, which describes a learning experience in which one expects that (a) failure to learn will inevitably constrict or remove one’s sense of agency, or (b) fits of learning will recover, expand, or maintain one’s sense of agency. In this brief section, I will first introduce the aims of *compulsory learning* within the lives of Smiles and Bones, followed by a short discussion of the dimensions through which these aims are realized.

One way to consider the aims of *compulsory learning* are that they represent the tenuous though essential aspects of daily life that Smiles and Bones negotiate in order to recover or expand a sense of agency. I will discuss briefly, omitting illustrative quotes for the sake of space, the following aims: (a) physical safety, (b) heightened self-worth, (c) access to and appropriation of basic resources, and (d) the ability to realize ideals related to each of their overlapping identities. *Physical Safety:* Since Smiles and Bones feel compelled to engage in mobile practices that are themselves characterized by the imminent threat of real and perceived danger, participants pursue the necessary resources, skills, and dispositions to realize a measure of safety across mobile

practices. Their pursuit of such safety extends beyond high-risk freight-hopping practices to include traversals across and temporary dwellings in blighted and potentially dangerous urban spaces. *Heightened Sense of Worth*: Against mainstream perceptions and stereotypes that position Smiles and Bones, for instance, as homeless, amoral “scum of the earth,” and of their mobile practices as irresponsible, deviant, and oppositional, Smiles and Bones feel compelled to adopt activities, discourses, and mindsets to counteract these dominant narratives and recover and expand their own sense of worth. *Appropriation of Basic Resources*: Of precarious economic means and circumscribed by limited knowledge of the opportunities embedded within local communities, Smile and Bones must engage themselves in daily quests to meet basic physiological demands. *The Realization of Ideals*: Premised on an overarching ideal of freedom, Smiles and Bones construct personal and social identities as freight-hoppers, musicians, urban campers, and street kids, and consequently feel pressed to gain the resources and skills necessary to meet ideals associated with each identity type.

Smiles and Bones pursue the ends of *compulsory learning* (i.e., physical safety, heightened sense of worth, access to and appropriation of basic resources, and the ability to realize ideals) through three interrelated dimensions: (a) discursive space, (b) event space, (c) bodily space. *Discursive Space*: Situated on the fringes of mainstream society, and aware not only of the negative stereotypes about themselves and of their social practices but also the dangers and limitations that characterize highly mobile street life, Smiles and Bones create for themselves *discursive spaces* from which they attempt to realize the various ends specific to their compulsory learning. *Event Space*: Each of the activities, or *event spaces*, in which participants engage have either an explicit or approximate structure, duration, and objective, while the events themselves also have various social implications. Consequently, Smiles and Bones realize the various ends of their *compulsory learning* through controlling, modifying, reframing, subverting, or participating more in line with the various events that constitute their daily rounds. *Bodily Space*: Bodily space refers to the lived experience of their mobile practices, which Smiles and Bones describe in varying degrees as strenuous, grueling, and oftentimes hazardous. As a result, Smiles and Bones realize various ends of their *compulsory learning* through modifying the lived experience associated with their *bodily space*.

### **Relevance to Conference Theme: Learning and Becoming in Practice**

As pertains to this year’s conference theme, this project argues for the consideration of a subjective disposition as a mediating link between learning and becoming. As discussed, the crux of *compulsory learning* pertains to the recovery, expansion, or maintenance of one’s sense of agency. Put differently, *compulsory learning* occurs when one recognizes he or she has a prodigious amount of “skin in the game,” so to speak. There is much to lose, in other words, in the event one fails to learn. If we assume this sense of agency facilitates sustained, interest-driven learning related to social practice, and if we think of *becoming* as necessarily related to notions of personhood and self-identity, one can begin to see perhaps a less direct link between learning and becoming. This poster argues that a sense of agency may serve as a *conduit to learning* and a *premise to becoming* in practice. One can learn a skill, for instance, yet until one perceives an acquired skill to matter in relation to some desired identity construction, such learning may not necessitate a sense of becoming. For instance, both Smile and Bones, who maintained relatively high GPAs throughout high school—based largely on what they considered to be their own “natural smarts”—never identified themselves as “scholars” or “school boys.” In fact, they chose to discontinue their school-based education since they perceived the accumulation of academic knowledge itself to be at odds with the life of a traveler, which was who they desired to become. Rather, “becoming in practice” may result from the recovery, expansion, or maintenance of agency, in other words, from *compulsory learning*. In short, *agency in practice* may presuppose *learning as becoming*.

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### **Acknowledgements**

This project would not have been possible without the critical feedback and continuous support of the Space, Learning, and Mobility Lab, including Rogers Hall, Kevin Leander, Katie Taylor, Ty Hollett, Jennifer Khan, and Ben Shapiro. I am also grateful for Pratim Sengupta and Rich Lehrer’s invaluable insights and comments.

# Sink or Swim: Understanding the Evolution of User Behaviors in an Online Educational Community

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**Abstract:** Online educational communities provide spaces for teachers to find resources, create instructional activities, and share these activities with others. Engagement with such online communities can be affected by how participants were initially recruited and supported. But what happens when these support and dissemination are removed? This study investigates the evolution of user behaviors after dissemination activities are completed. The results suggest that once dissemination activities ended, users' consumer behaviors continued while their contributor behaviors decreased.

## Introduction

Teachers are increasingly turning to online resources to customize lessons, update their lesson plans, and provide additional materials to meet their students' varied needs (Charles & Rice, 2012). In tandem, tools have been developed to facilitate teachers' selection and usage of online resources, and to establish online educational communities (OEC) around these resources (Windle, 2000). In an OEC, teachers can engage in different activities, such as actively designing instructional activities with selected resources, voluntarily sharing their designed activities, or learning from others (Nonnecke, Andrews, & Preece, 2006).

Studies of the long term patterns of activity in OEC show that some communities exist and thrive with growing number of users, while other communities shrink with fewer users and less participation (Iribarri & Leroy, 2009). Research has suggested that appropriate support and dissemination activities (e.g., workshops) can well keep users' interests and encourage their participation, and thus enhance online communities' development (Schlager, Fusco, Schank, 2002).

Different user types have also been identified based on their practices in an online community: "lurkers" generally take a non-participatory role and simply view other members' contributions. "Non-lurkers" take on a more active role by creating and sharing their content within the community (Bishop, 2006). Clear understanding of the usage pattern trends for different users in an OEC, especially their behavioral changes during and after dissemination activities, will add to the knowledge of how to attract new users, to increase the loyalty of existing users, and to improve the overall health of existing communities (Panciera, Friedhorsky, Erickson, & Terveen, 2010).

The purpose of this study is to understand the evolution of teachers' behaviors based around a free, web-based tool called the Instructional Architect (IA.usu.edu) (Recker, 2006). Within the IA online community, teachers can access online resources to create, publish, and share instructional activities (called IA projects) while also viewing contributions from other teachers. In particular, this study aims to identify what types of behaviors in the IA community are most affected when dissemination activities end, thus providing suggestions for how to sustain OEC.

## Research Design and Methods

This study addresses the following two research questions:

1. What were the usage pattern trends for *IA users* after dissemination activities ended (called the *no-dissemination period*)?
2. How did the *IA non-lurkers'* behaviors change between the *active-dissemination period* and the *no-dissemination period*?

The *active-dissemination period* (July, 2009 – June, 2011) refers to the time period with active support and dissemination activities (e.g., workshops) in the IA, while the *no-dissemination period* refers to the same length of time after dissemination activities ended (July, 2011 – June, 2013). IA's visitor traffic data were collected from Google Analytics and the IA database.

## Results

RQ1: Usage trends for all IA users within the IA online community during the no-dissemination period are shown in Figure 1. As can be seen, IA usage continued despite the end of active dissemination activities. Also, note the trough in usage happened during the summer break when teachers had fewer teaching responsibilities.

RQ2: The non-lurkers can be actively involved in the IA online community in the following ways: logging in, creating IA projects, publishing IA projects, copying others' IA projects, and using online resources. Table 1 compares non-lurkers' behaviors between *active-dissemination* and *no-dissemination periods* in terms

of these five activities. As can be seen, non-lurkers show declines for all five activities, with the largest drop in the “number of IA projects copied from others” and the smallest drop in the “number of IA public projects created”.

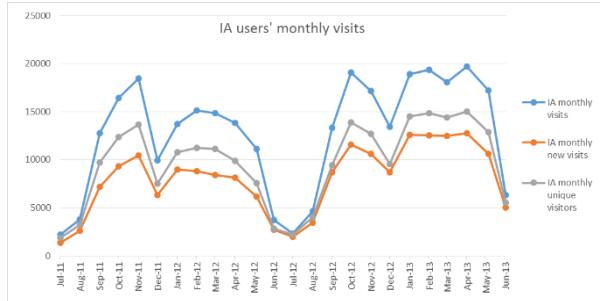


Figure 1. IA users' monthly visits during the no-dissemination period (July, 2011-June, 2013).

Table 1: A comparison of non-lurkers' monthly behaviors.

	Active-dissemination period			No-dissemination period			Percentage of change
	Mean	Median	SD	Mean	Median	SD	
# of Logins	594.38	486.00	360.55	314.88	250.50	269.45	-47.02
# of IA projects created	263.13	239.00	152.38	181.33	137.50	171.53	-31.09
# of IA public projects created	92.58	82.50	64.85	81.46	49.00	95.15	-12.01
# of IA projects copied	51.13	54.50	36.76	19.83	8.50	28.05	-61.22
# of online resources used	803.46	698.00	497.10	455.42	350.50	408.96	-43.32

## Conclusions and Contribution

This paper describes the differences in activity and behavior of users in the IA online community during and after active dissemination activities. With the end of active dissemination, users' consumer behaviors continued, which can be seen in the monthly visits data. However, users' contributor behaviors decreased, such as creating and sharing fewer IA projects. These results suggest that support and dissemination play a role in keeping non-lurkers' interest and loyalty. Future work will address the varying degrees of decline in non-lurkers' behaviors, examine lurker's behavior in more depth, and identify possible dissemination mechanisms to encourage active participation, thereby retaining the non-lurkers' interests and turning lurkers into non-lurkers.

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## Acknowledgements

This work was funded by NSF grant (#0937630). The opinions in this paper are those of the authors and not necessarily of the funding agency.

# Using Deficient Models as Scaffolds for Learning Engineering Concepts of Tradeoffs and Optimization

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**Abstract:** There is a need to teach core engineering concepts to elementary grade students. We present a novel approach using ‘deficient model’ i.e. a sub-optimal solution, to help students attend to design optimization and associated tradeoffs required to improve an engineering system. The nascent stage of this research prevents us from making conclusions. However, the framework highlights how distinct science education approaches can be synthesized and applied in the context of engineering education.

## Introduction

The recent National Research Council reports (NRC, 2010; NRC, 2012) highlight the need for elementary grade students to understand engineering concepts like design optimization and tradeoffs. Considerably less attention has been paid to this age group, where such efforts could serve as a “mainline” function for promoting technological literacy and stimulating long-term interest in mathematics and science (Capobianco et al., 2011). One of the few initiatives focusing on this age group is Boston Museum of Science’s curriculum – Engineering is Elementary (<http://legacy.mos.org/eie>). Further research is needed to explore additional pedagogies and mechanisms for teaching engineering concepts. We propose a new approach for helping elementary graders grapple with concepts of tradeoffs and optimization. Our approach draws on prior science education research using worked examples, negative examples and model-based learning.

## Framework

*Worked examples* provide an expert's (correct) solution to a problem for the learner to study and emulate (Atkinson et al., 2000). When worked examples are presented before unsolved problems, they channelize students' problem-solving attempts in productive directions leading to efficient strategies (Chi et al., 1989; Ward & Sweller, 1990). Such examples can similarly be used for effectively guiding problem-solving activities in an engineering context. In contrast, *negative examples* provide incorrect ways of solving a problem. Such examples are effective in problem-solving contexts as they discourage snap design judgments, thereby increasing accuracy of solution (Smoke, 1933). They help students identify design limitations (Haack, 1972) and can potentially lead them to focus on design optimization as a problem-solving task. We also know that *model-based pedagogies* help students build subject matter expertise and epistemological understanding of scientific knowledge (Lehrer & Schauble, 2006; White & Frederiksen, 1998). We consider model to be a simplified physical representation of a system of phenomena that makes its central features visible so that they can be used to generate explanations (Harrison & Treagust, 2000). Model-based pedagogies are most effective when students themselves construct and critique a model (Coll, France & Taylor, 2005). However, use of a single model or one worked example leads to 'functional fixedness' (Furió et al., 2000) in the science education context or 'design fixation' (Youmans & Arciszewski, 2012) in the engineering context. Students believe that there is only one 'right model' for depicting a phenomenon accurately. Similarly, engineers limit the probable solutions to a problem because of an overreliance on features of example designs presented to them. To tackle functional fixedness, science education researchers prefer to use multiple models (Lehrer & Schauble, 2006). However, in the engineering context, multiple example solutions can reduce the range and accuracy of design solutions (Jansson & Smith, 1991; Linsey et al., 2010).

In view of these challenges, we introduce the idea of using ‘*deficient model*’ – sub-optimal/inefficient design solution in the form of a physical model – for teaching design optimization and tradeoffs. As opposed to negative examples which represent incorrect solutions, a deficient model presents inefficient solutions requiring students to learn how to identify these deficiencies and optimize the design. Based on research with worked examples, a deficient model (a) shows students a (sub-optimal) sample solution, (b) provides a starting point, (c) provides a reference example for comparison, and (d) prompts students to develop rules that guide problem solving. Our approach also draws on limited research using negative examples by (a) showcasing inefficient solutions and providing a baseline for the students, (b) channelizing attention to limits of a design, and (c) countering design fixation and leaving exploration space open for students. We also use model-based pedagogy by having students analyze the deficient model and then construct an (emergent) optimal model.

Through this research, we will investigate how the use of deficient models as priming artifacts impact students' productive engagement with engineering concepts of tradeoffs and design optimization. Two types of deficient models will be used – Improvable model (inefficient but complete model that can be optimized by

modifying) and Partially optimal model (partially optimal but incomplete model that can be optimized by extending and modifying).

## Activity

We will use the context of designing a home plumbing system for this research. Two upper elementary grade classrooms will participate in the study. One grade will work with the improvable model and the other will work with the partially optimal model. Students will be first asked to critique the sub-optimal model and then subsequently build an optimal model by modifying or extending them using a limited amount of construction resources (serving as design constraint). They will measure the values of design variables (pipe length and diameter) and then use a software simulator to investigate the effect of different design decisions on the outcome variables (pipe cost, water pressure, water flow). For example, replacing a 1-inch pipe with 3-inch pipe reduces drop in water pressure at the end of the pipe but also increases cost of pipe. Students organize such findings in the form of rules of thumb for later use while designing their own emergent optimal model. These activities give students an opportunity to understand the sub-optimality of the deficient model, investigate the consequences of those deficiencies, establish relationships between different variables in the system and explore ways of constructing an optimal model. The deficient model will be used as a reference model while students build their emergent model using the rules identified before. Students will determine the optimal length and diameter of pipe for their emergent model based on given design goal – build a model as cheaply as you can (within a fixed budget of \$2000) yet meet the minimum pressure requirements set by the building engineer. We believe that these design constraints can trigger consideration of tradeoffs related to optimization decisions. Students will finally compare their improved model with the given sub-optimal model, share their design rationales and answer questions about the design that their peers might have.

## Conclusions and Implications

The nascent stage of this research prevents us from making conclusions. However, the framework and design of the study has implications for the communities' knowledge of engineering education pedagogy. Two primary contexts encapsulated in the conference theme are 'engaging in epistemic practices' and 'engaging in design'. The research idea presented here espouses these contexts by facilitating student engagement with design tasks requiring them to make tradeoffs and optimization decisions, critical concepts in engineering discipline.

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# **Intersections of Science Learning and Language Development within Scientific Argumentation: Implications for English Language Learners**

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**Abstract:** This piece contends that engaging in scientific argumentation simultaneously promotes second language acquisition through purposeful and authentic use of English, supports development of science content knowledge, and facilitates socialization into science practices. We explore the learning opportunities embedded within argumentation using a sheltered English immersion science classroom example. Through this examination, we provide direction for designing learning environments for students that promote these types of learning experiences.

## **Purpose**

Understanding the dialogic aspects of classroom life is crucial to comprehending the opportunities for students to engage in science. Such engagement in science discourse is fundamental to accessing the science being taught, learned and practiced in the classroom (Kelly, 2007). Therefore exploring the tensions that arise in teaching and engaging in science discourse is important to ensuring equitable educational opportunities for all students, especially English language learners (ELLs). The sheltered English immersion (SEI) model is an approach used to address the science education of ELLs, in which the teacher attends to both content and language development objectives (Echevarria, Vogt & Short, 2008). The purpose of this piece is to highlight the ways that an SEI classroom can enhance discourse opportunities by promoting the intersection of science learning and second language (L2) development through argumentation. We discuss features of the SEI environment that promote these experiences and provide insight into ways to increase opportunities for ELLs to engage in science.

## **Theoretical Framework**

A sociocultural perspective on science learning promotes enculturating students into the practices of scientific communities, which includes attention to the uses of language in science (Anderson, 2007). Anderson argues that “scientists are participants in communities of practice with shared linguistic and social norms, values, and patterns of activity” (2007, p. 18). Consequently, an important task for science teachers is to explicitly teach and engage students within the social, linguistic, and cultural practices of science (Kelly, 2007). Similarly, the sociocultural view in second language acquisition (SLA) places emphasis on how learners become users of an L2 (Lantolf, 2000). Combining these views, this piece examines the ways ELLs use their evolving L2 to perform interactive and expressive tasks that are fundamental to science, specifically those associated with argumentation. Argumentation was chosen because it is heavily dialogic in nature (Jiménez-Aleixandre & Erduran, 2008), encouraging students to generate, critically evaluate, and use evidence to support claims (Osborne, 2010). Additionally, this practice lets ELLs use their developing L2 through multiple modalities in authentic and meaningful tasks (e.g. reading and analyzing arguments). Little prior research on science discourse and practice has focused on students who have been historically marginalized in science education, including ELLs (Kelly, 2007). As such, this conceptual piece explores the educational potential of argumentation for ELLs.

## **Exploration of an Argumentation Classroom Example**

We suggest that argumentation is simultaneously a science learning opportunity, a language development experience, and an authentic practice through which students can become enculturated into the scientific community. Our perspective focuses on the ways that these learning experiences mutually support and inform one another. Given space constraints, only one classroom example will be used to illustrate this concept, although the final poster will contain more examples across language modalities (e.g. writing and reading). The following interaction was captured in a middle school SEI science classroom, in which students were learning about how relevant supporting evidence makes an argument more persuasive via a card sorting activity (see Table 1).

In this example, the students use their developing L2 to explain their reasoning as to whether a particular card illustrates relevant evidence for a claim. When Sofia says she can't accomplish this task well (end of turn 3) Eva helps her articulate her reasoning (first sentence in turn 4). Following this interaction, Sofia is able to explain her thought process for another card, having learned from her peer how to express her reasoning in English.

During this interaction, the students also deepen their understanding of the science content. Their language experience was supporting and reinforcing their growing understanding of antibiotics and bacteria, while the task provided an authentic purpose to use their L2. Additionally, these students became enculturated into a fundamental practice of scientists. When Eva pushes Sofia to explain her reasoning by asking “Why?” (turn 1) she demonstrates a key component of argumentation: persuasion. This example illustrates how interlaced these learning experiences are, as well as how these intersections further strengthen the other learning experiences’ outcomes.

Table 1: Transcript exemplifying learning opportunities within argumentation

Turn	Speaker	Transcript
1	Sofia	[Student chimes in and finishes reading aloud the card with the other student] –“make people very sick.” I think this here [Student points to irrelevant pile] because doesn’t support the claim.
2	Eva	Why?
3	Sofia	[Student rereads card] Because dice ( <i>it says</i> ) [student reads off card] “unfortunately not all bacteria are helpful, helpful. Harmful bacteria can invade the human microbiome through cuts, spoil food, microbiome through cut.” I think, yo no puedo hacer bien la cosa esta. ( <i>I can’t do this thing well</i> )
4	Eva	Okay, I think here is [Student points to cards in irrelevant pile] here are information because they are like not connecting in the claim because they don’t have any antibiotics and kills and bacteria [student points to cards in irrelevant pile], like B right? And here [student points to cards in the relevant evidence pile] they have, we have to see and read if they are [student points to claim card] antibiotics killing bacteria. And here this say [student points to card in relevant evidence pile] antibiotics kill bacteria, that’s why it’s here.

However, we do not propose that the mere inclusion of argumentation resulted in the students having these learning opportunities. In line with Berland’s (2011) work, we argue that multiple factors, such as the teacher’s role, were integral in enabling this triad of learning experiences. For instance, before beginning the card sort, the teacher instilled in her students the importance of articulating the “why” behind each card sort decision. The effect of this instructional strategy came across when Eva pushed Sofia to explain the reasoning behind her decision. Another teacher action, which is evident in Eva’s response to help Sofia, was the simplification of argumentation language. Before the card sort started the teacher made the language of the claim more accessible to her students by asking them, “If you had to say this claim in three words, what three words would you use?” Eva reminds Sofia of these salient words when advising her to read for “antibiotics”, “kills”, and “bacteria” (second sentence in turn 4).

## Implications for Education and Research

We argue that engagement in scientific argumentation presents numerous authentic opportunities for science and language learning not only to occur simultaneously, but also to strengthen and support one another’s development. However, a crucial aspect of such experiences is understanding effective supports for ELLs in using their developing language to access and engage in science learning through argumentation. Consequently, a task for future research will be to identify the key characteristics of the learning environment that promote these interactions.

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# **Exploring the Use of Elaborative Interrogation in an Introductory Physics Course**

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**Abstract:** Elaborative Interrogation, which has students read a passage from the text and respond to the prompt “Why is this true?” for a sentence from the passage, was employed in an introductory college physics course. We report initial results with regard to student accuracy and depth of reasoning, and detail the effect of sentence type on student responses. We also report the results of a reading survey that addressed students’ reading habits during the course.

## **Introduction**

Reading and comprehending science texts is a skill that is crucial to the future success of students in the STEM fields. STEM practitioners gain much of their knowledge through reading (Hurd, 1998), and professionals who are successful within their field employ many comprehension strategies in order to understand what they are reading (Holliday, Yore, and Alverman, 1994). However, little attention is paid to developing reading and comprehension skills within science courses (Felder and Brent, 1996).

One method that encourages students to read and comprehend the material in the textbook is the interrogation method, which prompts students to answer “Why is this true?” for a sentence in the passage that they have read previously (Smith, Holliday, and Austin, 2009). In this study, we explored the use of the interrogation method in an introductory physics course for non-physics science majors, not only to get students to read more often, but to better understand what they read. Specifically we posed the following research questions: (1) Do students use the textbook when answering interrogation questions? (2) How do student responses to the “Why is this true?” prompt vary with the sentence they are given to respond to? (3) How do student responses evolve throughout the semester and between homework and exams?

## **Theoretical Framework**

Elaborative interrogation is a question-based reading strategy in which readers are prompted to read the text and then answer a “Why” question based on the reading (Levin, 2008). This method was developed to aid in the learning of scientific facts through the reading of science texts. Results of interrogation studies were encouraging, as the method showed increased comprehension over more traditional comprehension techniques such as rereading (Smith, Holliday, and Austin, 2009). We expand on elaborative interrogation research by bringing the method into every-day instruction and focusing on developing reasoning skills when answering the “why” questions. Additionally, in this study we investigated the choice of sentences for students to respond to in order to identify sentences that allow them to deeply reason and respond beyond a definition or formulae.

## **Methods**

### **The Course and Textbook**

The study was conducted in a large enrollment (180 students) introductory algebra-based physics course for science majors at a large university in the northeastern United States. The textbook used in the course was “College Physics” (Etkina, Gentile, and Van Heuvelen, Pearson, 2013).

Each week, students were assigned homework with instructions to read the text and then answer two “Why is this true?” interrogation questions for given sentences from the text. Each homework assignment was graded, and the students were provided with minimal feedback. On the first exam and the final, interrogation sentences were also given. Two of the questions were exact matches to questions they had seen previously and the third was a similar question. A reading survey asking students to report what resources they used to answer the interrogation questions was also administered to students at the beginning and end of the semester.

### **Sentence Types**

As this was an exploratory study, we gave the students multiple sentence types to respond to. The first type was a fact statement or definition. The second type of sentence was characterized as a simple phenomenon prompt. These sentences provide students with simple phenomena such as collisions. The final type of sentence was characterized as a complex phenomenon. These sentences provide students with complex, concrete phenomena or occurrences such as analyzing an elevator ride, or the floating of a boat.

## Coding

Two independent coders evaluated each sentence for accuracy of physics, and depth of reasoning. Both were both coded on a 0-3 scale (3 being the highest). To check for reliability, both coders coded 20 percent of the student answers. Reliabilities of .93 and .89 were reached for accuracy and reasoning, respectively.

## Findings

### Comparing Responses Based on Sentence Type

We assigned a total of 7 fact statements, 17 simple phenomena, and 18 complex phenomena statements to the students throughout the semester. The mean reasoning score for the responses to fact statement sentences was 1.20, for simple phenomena, 1.32 and for complex phenomena, 1.87. Using an ANOVA we found that the level of reasoning students used when responding to complex phenomena statements was significantly higher than fact statements or simple phenomena ( $p$ -value < .01).

### Accuracy and Reasoning Throughout the Semester

We first compared homework accuracy to the accuracy on identical and similar exam questions. We used t-tests to test the significance of the difference in scores between homework and the exam. There was a significant positive change between identical and similar homework and exam questions (growth from HW1 to Exam 1, .4318,  $p$  < .01, HW2 to exam 2, .30,  $p$  < .01). To assess change in reasoning throughout the semester, we compared reasoning ratings from the first homework and the last homework of semester 1. There was positive growth in reasoning (.20), however it was not a significant gain ( $p$  = .093)

### Reading Survey

105 students responded to the survey administered in their lab sections. 35 students indicated that they used only the textbook to answer the interrogation questions, and an additional 47 students indicated they used some combination of the textbook and material from class. The remainder of the students indicated that they never used the text to answer the questions (23 students).

### Discussion

The initial results of this study show that throughout the semester there was growth in both students reasoning and the accuracy of their answers. While it is plausible that there are other reasons for students' growth in accuracy and reasoning, such as the nature of the course, this result is promising nonetheless. To answer the interrogation questions correctly and completely, the students must understand the material and be able to reason as to why the sentences are true, which is an important goal of any science class. Additional work will have to be done utilizing a control group to further test the effect of the interrogation sentences.

With regard to sentence type, there is a clear difference between the answers students give to fact statement and simple phenomena as opposed to complex phenomena. The students reasoned deeper when responding to the complex sentences. Further work using cognitive interviews will be done to better determine why students reason more deeply when responding to certain sentences.

Finally, the main goal of this study was to get students to read and interact with the text with more depth and frequency. Based on the initial survey results, it appears that by having the students answer the interrogation questions we encourage them to spend time reading the text and using the information to answer the questions.

While further analyses need to be done to determine the strategies students use when answering the interrogation questions and the effect the method has on student learning and reasoning, it appears that elaborative interrogation is a method that at the very least engages students in active reading of the text.

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# Fusing a Crosscutting Concept, Science Practice, and a Disciplinary Core Idea in Single Learning Progression

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**Abstract:** In this paper, we report on a learning progression that fuses systemic reasoning (cross-cutting concept) and ecology (core idea) in what we call “ecological systemic reasoning”. We used semi-structured interviews with 44 students (1<sup>st</sup> through 4<sup>th</sup> grades). The results revealed that a hypothetical learning progression begins with anthropomorphic reasoning as the lower anchor and ends with complex causal reasoning as the upper anchor for students in this age.

## Project Background

Recently, learning progressions (“descriptions of successively more sophisticated ways of thinking about a topic that can follow one another as children learn about and investigate a topic over a broad span of time”, NRC, 2007, p. 214) have been used to examine how students learn over time. For example, Songer et al. (2009) describe an empirically based, fused learning progression for ecology and scientific explanations used to guide the development of curricula and assessment items for elementary students (grades 4<sup>th</sup> – 6<sup>th</sup>). Although this fusion approach gives important insights into students’ developing abilities to fuse disciplinary core ideas and a science practice, they did not take into consideration a holistic approach that fuses the systems thinking as a cross cutting concept with ecology as a disciplinary core idea as students explain phenomena (a science practice). Grotzer and Bell (2003) showed that 3<sup>rd</sup> graders can learn to reason in more sophisticated ways when taught explicitly about causal reasoning. However, many students still lagged behind in understanding the global picture of species interdependency. Therefore, more empirical work is required to understand how younger students reason about species interdependency in ecosystems, specifically before formal instruction. This study builds on the literature in two ways: (1) it explores students’ reasoning of ecosystems before instruction and (2) it uses the systemic reasoning approach to identify a hypothetical learning progression for students’ systemic reasoning in domain specific content.

Chandler and Boutilier (1992) proposed a hypothetical reasoning model that applies to open systems, “dynamic system reasoning.” They proposed four properties for systemic reasoning: (1) systemic synthesis: i.e., understanding that a change in one component affects others; (2) systemic analysis: i.e., there are critical elements (like water molecules or sun) that are essential for the system (e.g., hydrologic system) to work and they are different from incidental elements (e.g., storms); (3) circular connectivity: which is the opposite of systemic synthesis where the students are asked to make the system from the independent elements; (4) dynamic recycling: i.e. molecules do not exit from the system but instead keep circulating in it. When examining whether students’ systems reasoning was ontologically different from Piaget’s formal operational reasoning or whether it is a kind of reasoning that develops at the “heels of Piaget’s formal operational reasoning,” they found out that there were significant statistical differences between the two kinds of reasoning. That is, students’ performance on the dynamic system reasoning task was a separate “ontogenetic” category different from that of Piaget’s. Building on Chandler and Boutilier’s framework, we have adopted two categories of systemic reasoning (circular connectivity and systemic synthesis) and developed a hypothetical learning progression for those two categories. Note, that we also studied the learning progression for the other two categories, but due to space limitations, we focus on those two categories because they required students to utilize two opposite skills: one of constructing the ecosystem from individual components, and one of analyzing the components a pre-existing system. To organize the study, we pose the following research question:

What are the patterns in 1<sup>st</sup> to 4<sup>th</sup> grade students’ systems reasoning with regard to constructing a complex food web (circular connectivity), and with regard to relating the effect of changing one population on others in the food web (systemic synthesis)?

## Method and Data Analysis

The participants in this study were 44 1<sup>st</sup> through 4<sup>th</sup> grade students in a suburban Midwestern school. We used semi-structured interviews to probe students’ ideas about each of the four systemic reasoning categories. All interviews were transcribed verbatim and then the transcripts were checked against the recording. We had an iterative process of several rounds of coding: we first started by looking at students’ answers, took a small sample and used constant comparative method (Strauss & Corbin, 1998) to derive general codes about students reasoning in the system. After deriving initial codes, we went back to the data and re-coded students answers

accordingly and then went back to refine our codes, in an iterative process consistent with the learning progression approach (Collins et al., 2004).

## Findings and Implications

The results of this study revealed 5 levels in the hypothetical learning progression for systemic reasoning: the lower anchor (level 1) was anthropomorphic reasoning where students projected human characteristics or personal liking to their reasoning with no reference to any external mechanism or cause. Level 1.5 was anthropocentric reasoning where students related their choices and reasoning to what they were used to in real life: they still did not utilize an external mechanism that considered underlying causes of the event, but at the same time, they did not relate the reasoning to personal liking of human characteristics. Instead they reasoned from their common everyday experiences. Level 2 was simple causal reasoning where students identified one external factor that was influenced by the change. Level 3 was semi-complex causal reasoning which took into account more than one external factor affecting the phenomena, but at the same time did not recognize how all populations influence each other. The upper anchor, level 4, was one where students recognized the network of relations in the system.

The results of this study revealed that many students could reason about ecosystems before exposed to formal instruction. The concentration on shelter as a condition to construct an environment concurs with Lehrer and Schauble's (2012) finding that elementary students' conception of ecology in general starts with anthropomorphic reasoning and develops to consider shelter as an important factor and moves on to add factors reasoning about the influence of changing one population on all populations of the ecosystem. Moreover, similar kinds of reasoning to this study were found by Leech et al. (1996), who found that even older students are more likely to consider effects on direct populations than those of indirect populations suggesting that lower elementary students reason in similar ways to middle and high school students. This means that with proper instructional materials, lower elementary students are likely capable of thinking at a systemic level and capable of appreciating the complexity of interactions in the ecosystems. This is supported by research that showed that proper software models (Eilam, 2012) together with organized instruction allows successful learning of systemic reasoning in the context of ecosystems.

This study is important for two reasons: first, it fuses a disciplinary core idea and a crosscutting concept to develop a unified learning progression of how students reason (a science practice) about ecology; and second, it continues the conversation of how learning progressions need to be revised in an iterative process that best captures students reasoning so that we can design effective instruction that fosters desired learning goals for our students. It is important to start conversations about the criteria of developing learning progression and what can be fused or teased apart because this renders learning progression research more coherent and directs future research agenda in the field.

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# Redefining Engagement and Participation: The Co-Construction of Student Learning Practices

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**Abstract:** We examine three student learning practices (SLPs) – listening, presenting, and making and using records – central to participation and engagement in academically ambitious mathematics classrooms. These SLPs, enacted to learn academic content, are *means* to learning outcomes and *outcomes* in their own right. We study these SLPs in an elementary mathematics laboratory in which SLPs are supported and developed. Grounded in practice, this analysis enriches concepts of participation and engagement and advances our understanding of SLPs.

## Purposes

Students' learning in classrooms is often equated with their engagement and participation in classroom activities. Yet, engagement and participation are associated with how many students appear to be sitting quietly and answering questions. We complicate these views, unpacking specific practices that students enact in order to participate and engage in learning mathematics in classrooms, and illuminate the work of teaching to support the SLPs of listening, presenting, and making and using records.

We examine: listening, which encompasses the practices associated with developing an understanding of the ideas in the classroom discourse; presenting, which includes representing mathematical thinking for the purpose of explaining to others; and making and using records, which includes keeping track of the significant mathematical ideas in the class. Analyzing the interaction of these SLPs, we identify work that both teachers and students do in order to build and support classroom participation and engagement.

## Theoretical framework

Students' use of instruction – their engagement with teachers, content and each other – comprise the work of learning and lead to learning achievement (Cohen, Raudenbush, & Ball, 2003). Researchers posit a set of student practices that might be involved in the work that students do to learn – Lampert's (2001) inquiring, discussing, thinking, reading carefully, and examining closely, Fenstermacher's (1986) reciting, practicing, seeking assistance, reviewing, checking, and Ericson and Ellet's "attending to instructions and explanations carefully... practicing with an eye to proficiency, appraising carefully" (2002, p. 5). SLPs enable students to be successful users of classroom resources, and they support students' abilities to be a resource for themselves and others. Research has implied that SLPs are crucial to learning outcomes (Dewey, 1902/2001; Fenstermacher, 1986), but researchers have not operationalized SLPs or the ways in which they are constructed in classrooms.

## Methods

We study SLPs in the context of a two-week elementary mathematics laboratory (EML) in which these practices are developed with fifth grade students. The nature of the laboratory, the lesson plans, and the practice of "public teaching" provide a setting that supports collective observation and analysis of teaching and learning, making it an authentic context to investigate SLPs (Ball, Mann, Shaughnessy, Suzuka, & Thames, 2013). We ask the following: What SLPs are constructed, and by whom, in the context of the EML? What is the work of teaching to support the construction of the SLPs?

We analyzed video recordings, lesson plans, student work, field notes, and memos written during the EML to identify which SLPs were being taught, for what purposes, and the ways in which they were co-constructed. We used a grounded-theory approach (Glaser & Strauss, 1967). We focus on three SLPs that emerged from an earlier study (Goldin & O'Neill, 2013) and were also a focus of instruction in the EML (Ball & Shaughnessy, 2013).

## Results

Our analysis of three SLPs provides insight into the individual and collaborative nature of the SLPs and reveals the ways in which these practices operationalize participation and engagement. The study traces the development of these SLPs across time between the teacher and students in the context of specific mathematical work.

Analysis of SLPs suggests that listening is used to develop an understanding of the ideas in the classroom discourse in the EML. It is an activity to make sense of a topic or question that is the focus of

classroom inquiry for the purpose of using and evaluating other's ideas and building understanding. Here, listening in the classroom is associated with seeing and understanding other's thinking and noticing different approaches and solutions. Students' work presenting in the EML is comprised of publicly articulating ideas for the purpose of explaining to others. The analysis surfaces students' work presenting, and the ways the teacher co-constructs students' presentations by scaffolding, modeling, and doing some of the work with students. Making and using records includes the private and public efforts to record and create documents that keep track of the significant mathematical ideas in the class. This practice includes using a record of one's own mathematical work, organizing the various mathematical tasks in a single notebook, and recording ideas from the whole class. This practice creates records that are intended to serve the learner(s) in the moment as well as provide a resource to return to at a later date.

This study also focuses on these SLPs as a group, as component parts of the work that students and teachers need to do in classrooms to learn. These are SLPs that are particularly salient in crowded classrooms, and are fundamental to learning in classrooms with others. Regarding teaching practice, we illustrate the ways in which there might be overlapping teacher moves that themselves have dual purposes – to scaffold what is involved in presenting while also facilitating listening, for example. Results highlight the ways that these individually and collectively held SLPs develop over time. Working on these SLPs necessitates explicit teacher attention and support as the teacher models and scaffolds the individual and collective construction of SLPs.

## Significance

This analysis brings forward the nuances present in classroom participation and engagement and is useful for helping teachers, administrators, and researchers "see" the individual and collaborative forms of participation and engagement. Identifying teachers' work with students to develop SLPs illuminates how instruction can leverage and equalize students' access to and engagement with ambitious content. This work builds on scholarship that details the ways in which deliberate teaching that supports SLPs can "be central to the attainment of equity" (Boaler, 2002, p. 239). Further, this work has direct implications for how teachers might work with students. Focused on practice – students' SLPs and the practices of teaching that support them – this study improves our understanding of the work that students do to learn and supports the design of instruction that enables the successful development of these SLPs.

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## Acknowledgments

The authors would like to acknowledge the continued support of the EML research group.

# Reflective Decision Making within the Discourse of Urban Elementary Engineering Classrooms

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**Abstract:** The emergence of engineering in K-12 education has promoted the need for research on discursive practices associated with successful pre-college engineering. Specifically, elementary students need support for engaging in collaborative, reflective decision-making during engineering design activities. In this poster, we describe an initial phase of work that looked to identify connections between elementary students' reflective decision-making linguistic practices and students' community/home-based linguistic practices.

## Introduction

In this work, it is our intent to help students and teachers become aware of the disciplinary discourse practices of engineering design, and how these intersect with their "everyday," or personal discourse practices. Elementary students' engagement in engineering is not a new phenomenon, but the National Research Council's recent *Frameworks for K-12 Science Education* (2012) and the *Next Generation Science Standards* (Achieve, Inc., 2013) derived from the *Frameworks* brings urgency and importance to the task of exposing young students to the practices and big ideas of engineering. This study specifically focuses on promoting and supporting students' *reflective decision-making* in collaboration with others (NRC, 2012; Schön, 1987). The National Research Council (2012) writes, "Engineers, too, make decisions based on evidence that a given design will work; they rarely rely on trial and error." *Reflective decision-making* by a group of people requires tools for interaction, including ways of communicating engineering ideas and ways of thinking like an engineer (Atman, Kilgore, & McKenna, 2008).

This poster focuses on Phase One of a larger study and should be considered work in its early stages of development. Specifically, we highlight work with teacher researchers in identifying the practices and linguistic patterns associated with *reflected decision-making* in elementary students' engineering planning and design. The significance of this work is:

- Advancing educators' knowledge of how to identify and build upon intellectual and linguistic resources that students bring to engineering design processes.
- Empowering educators to support young students' development of a reflective stance toward engineering design, in preparation for a society that increasingly demands technological literacy of its citizens.

## Theoretical Approach

This study utilizes a "resources perspective" (Hammer & Elby, 2003) for recognizing the intellectual and linguistic practices that children from urban communities bring to engineering design processes. A variety of challenges associated with urban schools have often led to the portrayal of students in ways that are consistent with a "deficit perspective" on performance (Varelas, Kane, & Wylie, 2010). In contrast, educators and researchers who adhere to a "resources perspective" (e.g., Bang & Medin, 2010; Emdin, 2011) argue that numerous characteristics of urban communities, schools, and students can be interpreted as resources rather than challenges or deficits.

## Methodological Approaches

For this study, we utilized a case study approach (Yin, 2009) in order to recognize elementary students' reflective discourse practices during a pre-engineering unit focused on motion and design. Specifically, the linguistic practices utilized within a group of four, 4<sup>th</sup> grade African American boys while engaged in the design of miniature drag racing vehicles were examined for this study. The full research team, which includes educational researchers and classroom teachers, convened twice a month in order to examine and analyze collected data, including video recordings and transcribed classroom conversations from four classroom interactions. Audio recordings and field notes from these research meetings also served as additional data sources. We identified patterns and themes from the corpus of data via discourse analysis (Gee, 2001) grounded in the particular analytic approach of microethnographic study of classroom cultural practices (Bloome, Carter, Christian, Otto, & Shuart-Faris, 2005).

## Preliminary Findings

Preliminary coding of transcribed class sessions and team meetings has raised two themes of ongoing interest to be investigated further in the microanalysis. The first is the role of power within the design team's negotiations. We find that design proposals, decisions, and suggestions for redesign are communicated via a synthesis of engineering-specific language and everyday, personal expressions, and that engineering specific language plays a role in elevating the status of students' ideas. We are exploring this theme by asking how does the appropriation of specific everyday or discipline-specific discourse by participants shape the exchange and adoption of ideas. The second theme that has emerged is the distribution of physical manipulation of materials with other linguistic modes as contributing to the design activities and reflection (Aurigemma, Chandrasekharan, Nersessian, & Newstetter, 2013). In what way does physical manipulation of materials contribute or distract in shaping the discourse along with other linguistic resources? A detailed microanalysis of transcripts from classroom engineering experience will allow our research team to explore which interactions of multiple resources (everyday and disciplinary language, physical manipulation) result in design changes or reflections.

## Relevance to Conference Theme: "Learning and Becoming in Practice"

This work contributes to the conference theme through its specific focus on cultivating ways of recognizing and building upon students' intellectual and linguistic resources. Developing ways for recognizing students' strengths is accomplished by integrating three focal domains for inquiry -- big ideas in engineering design and discourse, students' sense-making, and issues of race, culture, and language. By supporting inquiry through structured settings of professional work and resources for documenting and analyzing practice in engineering, we look to contribute to the theoretical and practical knowledge-base for pre-college engineering activities in elementary school settings.

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# Adventure Learning @ the Learning Sciences

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**Abstract:** Teaching the general public and K-12 communities about scientific research has taken on greater importance as climate change increasingly impacts the world we live in. The Adventure Learning approach to designing learning environments was used to engage high school students in authentic climate science inquiries in Greenland. The learning sciences represent an important next step in the evolution of Adventure Learning.

Teaching the general public and K-12 communities about scientific research has taken on greater importance as climate change increasingly impacts the world we live in. Science researchers and the educational community have a widening responsibility to produce and deliver curriculum and content that is timely, scientifically sound and engaging. To address this challenge, in the summer of 2012 the *Adventure Learning @ Greenland* (AL@GL) project, a United States' National Science Foundation (NSF) funded initiative, used hands-on and web-based climate science experiences for high school students to promote climate and science literacy. This poster reports on an innovative approach to education and outreach for environmental science research known as Adventure Learning (AL) and seeks to engage the learning science community in a dialog around research on Adventure Learning.

AL is a curricular approach that combines face-to-face and online learning experiences. The AL framework was originally tested through a series of circumpolar Arctic expeditions where a team of adventurers traveled via dogsled between remote villages (see the GoNorth! project at <http://www.polarhusky.com>). The AL framework as enacted by the GoNorth! project proved to be extremely successful, effectively reaching millions of students from around the world (The Learning Technologies Collaborative 2010).

AL was originally defined by Doering (2006) as “a hybrid distance education approach that provides students with opportunities to explore real-world issues through authentic learning experiences within collaborative learning environments” (p. 198). Building upon this definition, Veletsianos and Kleanthous (2009) define AL as “an approach for designing teaching and learning environments, whether those are online or hybrid, or used in face-to-face or distance education contexts” (p. 91). The framework associated with AL for the purposes of design, development, and implementation has nine principles that operationalize the approach (The Learning Technologies Collaborative 2010).

The purpose of AL@GL was to engage high school students in the US, and in Greenland, in atmospheric research that is being conducted in the Arctic to enhance climate and science literacy. Climate and science literacy was explored via three fundamental concepts: radiation, the greenhouse effect, and climate vs. weather. Over the course of the project, students in each location engaged in activities and conducted experiments through the use of scientific instrumentation. Students were taught science research principles associated with an atmospheric observatory at Summit Station, Greenland with the objective of connecting climate science in the Arctic to student’s local environments.

Summit Station is located on the Greenland Ice Sheet [72°N, 38°W, 3200 m] and was the primary location of interest. Approximately 35 students at multiple locations in Idaho, USA, and Greenland participated in the hybrid learning environments as part of this project. The AL@GL project engaged students in an inquiry-based curriculum with content that highlighted a cutting-edge geophysical research initiative at Summit: the Integrated Characterization of Energy, Clouds, Atmospheric state, and Precipitation at Summit (ICECAPS) project (<http://www.esrl.noaa.gov/psd/arctic/observatories/summit/>). ICECAPS is an atmospheric observatory focused on obtaining high temporal resolution measurements of clouds from ground-based remote sensors including radar, lidar, infrared spectra and others. ICECAPS also launches radiosondes twice daily. This large suite of complementary observations are providing an important baseline understanding of cloud and atmospheric conditions over the central Greenland ice sheet and are supporting Arctic climate research on cloud processes and climate model validation. ICECAPS measures parameters that are associated with those identified in student misconceptions, for example, different types of atmospheric radiation, the effect of greenhouse gases, and climate versus weather (see also Haller et al., 2011). Thus, ICECAPS research and the AL@GL project combined to create a learning environment and educational activities that sought to increase climate literacy in high school students as well as communicate important atmospheric research to a broader audience.

Students participating in AL@GL activities were given a pre/post survey that measured content knowledge, understanding of science inquiry and the nature of science, and perceptions of human ecological impact. The survey instrument was developed specifically for the AL@GL project and included questions

modified from the Student Understanding of Science and Scientific Inquiry (SUSSI) instrument (Liang et al., 2008), and the New Ecological Paradigm instrument (Dunlap et al., 2000), along with content specific questions (e.g. What is a cloud?). Pre surveys were administered to students in Greenland and the US prior to AL@GL activities. Post surveys were administered immediately following AL@GL activities and prior to students departing for home.

The pre/post assessment of student content knowledge produced mixed results. Total scores across the multiple-choice items relating to understanding of science inquiry, the nature of science, and perceptions of human ecological impact remained essentially unchanged for students in Greenland and the US after participating in the program. However, short-answer responses indicated that students' understanding of key climate topics, including clouds, radiation, greenhouse effect, and weather and climate, all increased. An increase in understanding is evident for students in Greenland and the US across all four topics. Overall, percentages were higher for students in Greenland than for students in the US. These results represent a limited view of student experience. Therefore, more focused research avenues need to be explored to understand the impact of the AL approach on student learning.

The learning sciences represent an important next step in the evolution of Adventure Learning. The seminal work of Bransford, Brown, and Cocking (2000) shifted the focus from instructional design for memorization of information to learning for understanding and the application of knowledge. There is much we can gain from the learning sciences as it relates to Adventure Learning that will greatly inform the next iteration. Three learning sciences paradigms will serve as the starting point for research on Adventure Learning. The paradigms of constructionism (Kafai, 2006), case-based reasoning (Kolodner, 2006, Kolodner et al., 2003), and project-based learning (Krajcik & Blumenfeld, 2006) each stand to inform rich avenues of inquiry for future Adventure Learning projects. The Design Based Implementation Research (DBIR) (Penuel, Fishman, Cheng, & Sabelli, 2011) approach is the perfect methodology for exploring the iterative back and forth between research and education. Thus, future Adventure Learning research, including the NSF EPSCoR *Managing Idaho's Landscapes for Ecosystem Services* (MILES) project, will implement a DBIR methodology.

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## Acknowledgments

This work was made possible by NSF grant #1240700.

# Visualizing Three-Dimensional Spatial Relationships in Virtual and Physical Astronomy Environments

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**Abstract:** Students used both virtual and physical models in a middle school lab that teaches the cause of lunar phases. Phase 1 compared two virtual models – a complex 3D model vs. a simplified 2D model. Students who used the 3D model had higher learning gains. Phase 2 compared activity sequencing. Preliminary results indicate that students with high prior knowledge benefit from using the virtual model first. Further study may confirm if this result is statistically significant.

## Introduction

We report on the development and testing of a “Visualization Lab,” which includes both physical and virtual models, designed to teach middle school students about the cause of the Moon’s phases and eclipses, phenomena that require students to visualize complex 3D relationships amongst the Sun, Earth, and Moon. The virtual component of the lab was implemented mainly in the WorldWide Telescope (WWT) computer program, an immersive astronomy data visualization environment. While visualizations hold promise for improving science education, research results on efficacy to date have been mixed. When implemented poorly, visualizations do not contribute to student learning, and in fact, students can become overwhelmed or confused, especially if the visualizations are not well-matched to student ability (ChanLin, 2001). However, Linn and Eylon (2011) cite research that suggests the tremendous promise of visualizations, when implemented correctly. Multiple studies support the idea that a blend of virtual and physical models may be more advantageous than one or the other alone (e.g. Liu, 2006). To date, little research has been done on optimal sequencing of virtual/physical models in classrooms, but Carmichael et al. (2010) have found evidence that students may benefit from using a physical model prior to the virtual model. We seek to build on this body of knowledge in our work.

## Methods, Assessment, and Results

We use a quasi-experimental method to compare different iterations of our Moon Lab. To assess student learning, we created and used identical pre- and post-tests that include multiple choice content questions about the Moon’s phases, and open response questions that probe understanding of the cause of the Moon’s phases. The multiple choice questions were selected from the Astronomy and Space Science Concept Inventory (ASSCI, Sadler, 2009), a compilation of distractor-driven multiple choice questions. Open-response questions embedded throughout the activities were scored using a Knowledge Integration (KI, Linn, 2000) rubric.

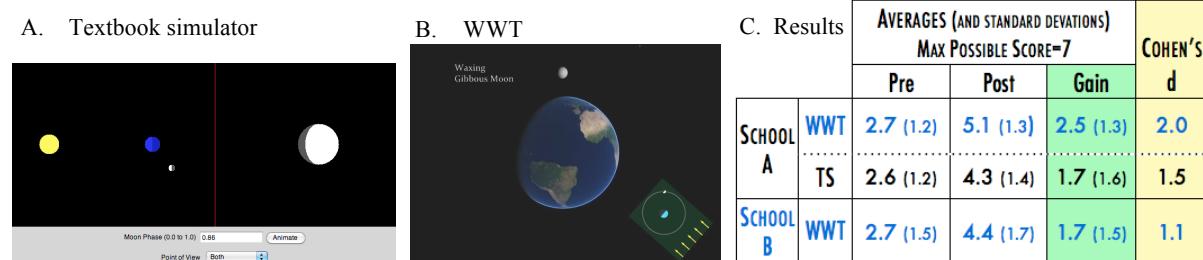


Figure 1A. & B. show screenshots of the Textbook simulator and WWT respectively. Figure 1C. shows a comparison of average pre/post-test scores, gains, and Cohen’s d effect sizes for students in School A who used WWT vs the Textbook Simulator (TS), and for students in School B who all used WWT.

## Phase 1

Phase 1 used a treatment-control design to compare learning results in students who used the complex 3D visualizations in WWT as the “virtual model” vs. those who used a traditional 2D simulator. We tested the first iteration of the lab with a sixth-grade teacher at a public middle school in a suburban Eastern Massachusetts town (School A), who teaches about 80 students in four classes. Each class had one day of pre-assessment; one day of instruction with the physical model (Styrofoam ball and lamp); two days of instruction with the virtual model; then one day of post-assessment. The teacher divided her students into groups (two treatment and two

control classes) with comparable student ability. The “treatment” group used WWT as the computer simulation, and the “control” group used a 2D simulator recommended by the students’ textbook, and already in use by the teacher. The simulator can be found at <http://www.astro.wisc.edu/~dolan/java/MoonPhase.html>, which is used in Activity 81, pg. F-48, of *Issues and Earth Science* (University of California, Berkeley, 2006). We refer to the 2D visualization as the “textbook simulator” or “TS” and the 3D visualization as “WWT.” Figure 1 shows sample screenshots of both the TS and WWT. Students in both Phase 1 groups (WWT and TS) showed strong learning gains (see Figure 1), but the WWT group outperformed the TS group ( $t$ -test  $p=0.03$ ;  $N=77$ ).

## Phase 2

We tested a second iteration of the VizLab with one eighth grade teacher and 70 students at a public middle school in an urban Eastern MA city (School B). For this phase, all students used WWT as the virtual model, but we tested two different sequencing of activities: virtual, then physical; vs. physical, then virtual. The program included one day of pre-assessment; one day with the first intervention; one day with the second intervention; one day using a blend of both interventions; and one day of post-assessment. Figure 1 (third row) shows learning gains and Cohen’s  $d$  effect sizes for all students in School B. The effect size measured at School B is smaller than that of both treatment and control groups at School A, but the demographics of the student populations at the two schools are very different.

We analyzed a median split of the pretest multiple choice scores and found that students with low prior knowledge benefited slightly from using the physical model first, while students with high prior knowledge benefited from using the virtual model first (see Table 1). We hypothesize that students with low prior knowledge had trouble interpreting the complex 3D computer visualization because they were not familiar enough with the mechanics of the Earth-Sun-Moon system to understand what they were looking at in the computer model. We are unsure why the students with high prior knowledge benefitted from seeing the 3D visualization first, but we hypothesize that their high level of engagement with the program could have been a factor. Further study with a larger sample size is needed to confirm the statistical significance of this result.

Table 1: A comparison of student learning gains in Phase 2.

Group	Low prior knowledge (pretest $<3$ ) Average Gain (SD), N	High prior knowledge (pretest $\geq 3$ ) Average Gain (SD), N	t-test comparing Low/High groups.
<b>Physical -&gt; Virtual</b>	Gain=2.64 (1.60), N=14	Gain=0.88 (1.58), N=17	$t=3.00$ , $p<0.01$
<b>Virtual -&gt; Physical</b>	Gain=2.10 (1.04), N=11	Gain=1.71 (1.16), N=17	$t=0.89$ , $p=0.38$
<b>t-test comparing model order</b>	$t=0.99$ , $p=0.33$	$t=1.73$ , $p=0.09$	

## Conclusions

Research shows that students of different ability learn differently from visualizations. ChanLin (2001) found that novice students with low prior knowledge learn better with static graphics, while experienced students with high prior knowledge learn equally well with dynamic visualization or static graphics. In contrast, Hays (1996) reports that middle school students with limited skill in visual processing had stronger learning gains from computer animations than from static pictures, through the use of guided explorations. Our preliminary results indicate that sequencing of virtual+physical models may need to be optimized based on student prior knowledge. Further work could illuminate how students of differing ability interact with visualizations.

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# Upper-Level Physics Students' Perceptions of Physicists

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**Abstract:** As part of a longitudinal study into identity development in upper-level physics students, we used a phenomenographic research method to examine students' perceptions of what it means to be a physicist. The results revealed four different categories. We find a clear distinction in the exclusivity students associate with being a physicist and the differences in the importance of research and its association with being a physicist. A relationship between perceptions of physicists and goal orientation is indicated.

## Introduction

The development of a professional identity is a key part of student development. The development of an appropriate subject specific identity is a strong influence on retention within a discipline. In the context of physics there is a strong link between level of identification with being a physicist and whether or not a student has settled on a physical science career (Barton & Yang, 2000). Understanding how students get to the point where they have achieved a strong level of identification with being a physicist is a complex undertaking and involves investigating multiple aspects of students' relationship with physics. These aspects include: examining students as they practice (do physics); who they are practicing with (their community of practice (Lave & Wenger, 1991)) and their personal identity (experiences, attributes and perceptions that shape their relationship with physics). In this poster we explore upper-level physics students' perceptions of what it means to be a physicist.

## Context and Methodology

The primary data sources are semi-structured phenomenographic interviews with students recruited from upper-level physics courses at a large midwestern university. Phenomenographic research typically focuses on a relatively small number of subjects and identifies a limited number of qualitatively different and interrelated ways in which the subjects experience and perceive a phenomenon. Our interviews focused on several topics including identity formation, epistemological sophistication, and metacognition. 21 students ranging from sophomores to seniors (18 male) participated. Our approach, based on the theory of variation and awareness (Marton & Booth, 1997) is grounded in the assumption that there are a limited number of qualitatively different ways in which something that is experienced and perceived – such as what it means to be a physicist – can be understood. From the theory, the goals of a phenomenographic analysis are to seek these qualitatively different ways and the variations thereon. In our study, the students' responses to questions were analyzed using an iterative process involving examinations of the video and transcripts with a particular focus of awareness on one aspect of the data with each sitting (for example: their experiences with research). The variation amongst critical aspects was utilized to form descriptions (outcome space) of the different perceptions of physicists. It is important to note that the interviews were focused on discovering the different students perceptions of being a physicist (phenomenographical) and how that relates to their current studies at a particular time in their undergraduate career as opposed the personal meaning of being a physicist to these students (phenomenological).

## Results

From our analysis of the interview data, four distinct categories of description emerged for students' perceptions of physicists. We briefly describe the categories below.

### **Physicists Are Researchers Who Answer the Unanswered Questions. (High Research/Mastery):**

Students in this category believe that physicists answer the unanswered questions and they do so by conducting "new" research. *"Abbey: I would say a physicist is someone who is trying to answer some of the unanswered questions, trying to prove the impossible."* Students have a passion for answering the questions that remain unanswered and see physics as a tool to do so. To do physics research is an important occupation but is dependent on the fact that one is not a physicist unless one is doing research. These students also discuss that they enjoy physics because it encourages a more complete understanding of a phenomenon. A focus on more complete understanding and the fact that these students do not believe that they will be physicists until they have contributed new knowledge/understanding to the physics community indicates a mastery orientation to physics.

## **Physicists Are Scientists Who Practice and Are Knowledgeable of Physics (High Research/Performance)**

Students in this category had a similar perception that doing research was important to be classified as a physicist. However, these students did not posit research as being a grand endeavor of answering unknown questions nor were they able to elaborate on what doing physics research might involve. Instead research is just "something" that is done to be "active" within the field. *"Dylan: Mostly the research I think that makes them a physicist, I mean, you get your degree and everything but its actually doing something that makes you a physicist."* These students when talking about the subject are orientated more towards performance. They believe that it is important to obtain a lot of knowledge of physics and that a certain amount of physics knowledge must be obtained to be considered a physicist.

## **Physicists Are People with a Certain Mindset (Low Research/Mastery)**

The students in this category believe themselves to be physicists already as they are involved in some capacity with physics, to them it is a way of approaching/viewing the world so that they understand it in a physical sense. *"Larry: I don't think you necessarily have to be, like, doing research actively to be a physicist, I just think you have to have an appreciation for physics and be involved with it in some capacity."* To these students there is no amount of knowledge to be obtained or no activity that must be completed to be a physicist besides having an inherent interest in the subject. The focus on understanding the world marks these students as being orientated towards mastering the subject.

## **Physicists Are People Who Are Committed to Physics (Low Research/Performance)**

Students in this category are focused on the fact that they are committed to the subject. The fact that someone has made a commitment to learning more about physics, is what makes someone a physicist. These students were also more likely to declare themselves a physicist at this point in their academic career as they have made a commitment to studying this subject for their extended future. *"Sally: I think they are a physicist when they have declared a commitment to it, (filled pause) to the subject, whether that is declaring a major or spending time studying it...but making a definite commitment to the subject."* These students place an emphasis on their knowledge being evaluated by an external source as an important element to being a physicist, which indicates that these students are orientated towards performance.

		Research	
Orientation	Mastery	High Importance Placed	Low Importance Placed
		Researchers who answer unanswered questions 8	People with a certain mindset 3
	Performance	Scientists who practice and knowledgeable of physics 7	People who are committed to physics 3

Figure 1. Categories and number of students categorized into each.

The majority of students' emphasis on research (Figure 1.) is likely a product of the university being studied. The faculty transmit a consistent message that research and obtaining a research experience is important. This message is received but what research actually entails and why it is important for a student to be involved in it in some capacity is content of this message that is not received by a substantial portion of the students involved in our study.

## **Conclusions**

We discovered four perceptions of what it means to be a physicist and found a relationship between these perceptions and goal orientation. This relationship should inform program developers that an emphasis on research should include an emphasis on what research entails. To many of the students in this study, research is just one more goal that one must achieve on ones trajectory to becoming a physicist. Perceiving research as a *goal to be achieved* rather than an *essential experience to be learned from* could have adverse effects to the development of a student's identity, their approach to research experiences, and ultimately their commitment to pursuing physics. This study is a snapshot of a particular time in this group of students undergraduate career and we expect answers to several of these questions to emerge through a longitudinal study of these students.

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# Designing and Validating a Story-Based Socio-Emotional Learning Assessment Instrument

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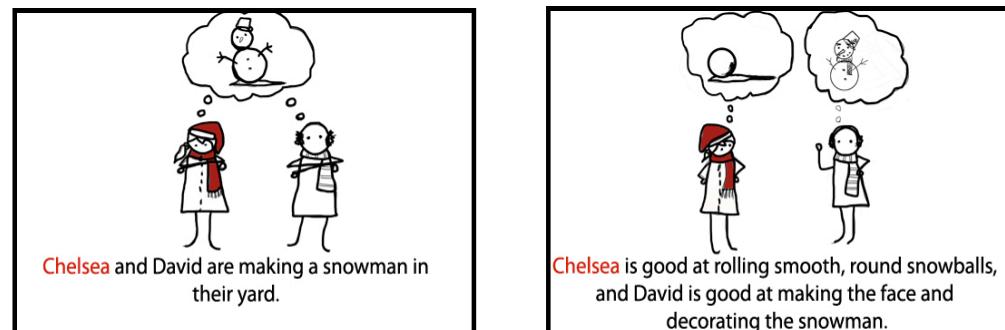
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**Abstract:** Current assessment instruments for socio-emotional skills typically focus on diagnosing dysfunction and need to be administered by teachers and parents. To explore socio-emotional learning in novel environments, the learning sciences community needs scalable, easy-to-administer research instruments that measure growth in normal children. In this paper, we report on an iterative design process and a series of validation studies for a story-based multiple-choice assessment tool that can be used efficiently by researchers in large-scale evaluations of technology-based socio-emotional learning (SEL) environments.

## Introduction and Theoretical Framework

Technology enhanced learning environments such as computer games and intelligent tutors provide the opportunity for early childhood learners to collaborate in order to acquire domain-specific knowledge (Aleven et al 2013). To succeed with technology-based collaborative learning—such as online education—learning researchers have increasingly focused on supporting development of socio-emotional skills. In order to gauge the success of emerging technologies for early childhood education with this important goal in mind, the research community needs assessment instruments that are reliable and sensitive enough to measure growth of social skills in normal children. This paper contributes a new assessment instrument targeting children in grades K-3<sup>rd</sup> for measuring three socio-emotional skills: 1) asking for help, 2) discussing differences in order to resolve conflicts, and 3) cooperating to solve problems. We document our process and progress towards designing a multiple-choice story-based SEL assessment tool (see example item in Figure 1), including multiple rounds of iteration and three validation studies. We discuss progress and remaining challenges.

We hypothesize that stories provide a valuable paradigm for assessing SEL with our target population. Storytelling has been used to gain insight into the thinking processes of a child. A child can envision him or herself as a character in the story and respond through self-projection within that reality (Hordstal, 2012),



If you were **Chelsea**, how would you solve the problem?



Figure 1. The "Snowman" story assessment item. Students read the top row and then choose between four possible outcomes (bottom row), from left to right: anti-social, social (preferred solution), non-social, and mildly social.

providing insights that would not be possible through direct observation. The capability for children to engage in such self-projection develops between the ages of four and six (Waytz & Mitchell). Although stories have drawn the attention of developmental psychologists and child psychotherapists to diagnose children's developmental disorders for therapeutic purposes (Kaland et al, 2005), they have not typically been used to assess socio-emotional skills in the broader student population.

Illustrated stories have been used in the past for assessing inquiry skills. Specifically, *Inquiry Comics* presents cartoons of children discussing scientific ideas in an inquiry process, from choosing a topic of investigation, to collecting data and concluding results (Ainsworth, Jong, Hmelo-Silver, 2010). However, the assessment items evaluate the characters' scientific investigation skills, not core SEL skills such as discussion and collaboration. This prior work provides inspiration for our own design and development effort.

## **Assessment Design and Validation Studies**

Our multiple-choice story-based SEL assessment tool includes twelve different story scenarios, four to measure each of the three skills. Each assessment item consists of two story panels, a main question, and four answer choices (see Figure 1). The first story panel introduces the context and characters. The characters are different in each story, and we have worked to balance assignment of gender and apparent ethnicity to characters. The second panel presents a conflict or challenge. Across all scenarios, the students see the same question: "If you were [the character] how would you solve the problem?" Students choose among four answer choices, presented in random order, which have been pre-assigned to the categories of Social, Mildly Social, Non-social, and Anti-social. Answer choices are a range of hypothetical actions the main character can choose to solve the problem. Ideas for the details of the stories and answer options were developed over a series of design workshops and pilot studies with the target age group.

We also developed and tested the digital version of this assessment tool using the Cognitive Tutor Authoring Tool (CTAT) platform (Aleven et al., 2009) with a total of 24 students in grades K-4. The online version adds three more features to the paper-based version. First, it provides a voice-over feature that is enabled by default when students login. The system plays pre-recorded voice recordings for each story panel, the main question, and the answer choices. Students can re-activate the audio recordings by clicking/tapping panels independently. Second, the digital version also supports data logging, either to the local computer or in an online depository. Third, the digital version can be installed on computers locally or accessed through the Internet using a URL. The combination of multiple-choice scoring and online data logging creates an opportunity for researchers to measure social emotional learning in large-scale studies.

Through user testing, we confirmed that our story assessment instrument provides convenience since students can answer questions relatively quickly; it's also easy to deploy online, especially now that the voice over feature allows students with reading difficulty to answer questions without human assistance. We conducted three validation studies with 283 students in K-3<sup>rd</sup> grade students and achieved moderate reliability scores across the three target social skills. We will share further evaluation details in subsequent papers.

## **Conclusions**

Our work demonstrates an online story-based assessment instrument to measure social-emotional growth in young children. Preliminary studies show that K-3rd grade children can comprehend and respond to the story scenarios without adult supervision. We still have challenges to address in terms of isolating the specific skills of interest and achieving the level of sensitivity desired for SEL assessment in the context of technology enhanced learning. Future work will focus on revising our story items to support greater sensitivity to growth.

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# Detecting Iterative Cycles of Engineering Design from Student Digital Footprints in Computer-Aided Design Software

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**Abstract:** As engineering design has been extensively incorporated in the Next Generation Science Standards, the need for understanding student design processes has never been greater. This paper demonstrates an innovative approach: computational process analytics (CPA) to analyze students' fine-grained digital footprints while using a computer-aided design tool to complete a solar urban design. CPA reveals critical student design patterns such as iteration and fixation, which provides researchers and teachers with invaluable insights about student learning.

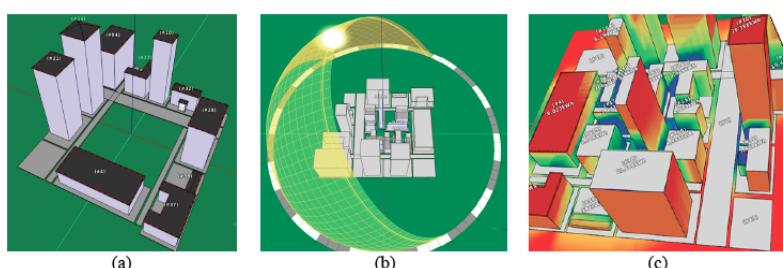
## Introduction

Ever since the National Research Council included engineering components in the national science standard framework (National Research Council, 2011), there has been an upsurge in attention on K-12 engineering education. Yet little research has investigated students' design processes and learning trajectories (Carr, Bennnnett IV, & Strobel, 2012). In this paper we propose to analyze students' process data when they are engaged in engineering design tasks using a novel computational process analytics (CPA) approach (Xie, Zhang, Nourian, Pallant, & Hazzard, 2014).

In particular, we investigate how CPA can provide multifaceted evidence to detect design fixation and iteration. Researchers have observed design fixation- as the design becomes more detailed, designers tend to develop inertia to revise the design (Purcell & Gero, 1996). Design fixation is detrimental because it limits iteration, an essential process to engineering design (Kolodner et al., 2003). Identifying design fixation is of utmost importance to researchers and teachers because a student who completes a design with no or few iterations will learn poorly from the design. This pilot study explores using CPA to detect design fixation and iteration during students' design of an urban area using passive solar strategies to optimize solar radiation heating in the winter and in the summer.

## The Solar Urban Design Challenge

The Solar Urban Design Challenge requires students to construct at least four buildings on a square city block (100\*100 square meters) surrounded by existing buildings of different heights. Students need to maximize the use of solar energy and to achieve optimal energy efficiency of the new construction. They also need to consider alternatives and generate at least three different design solutions. Students used Energy3D, a simplified computer-aided design (CAD) tool, to design the buildings within the city block. Two features of Energy3D – the Heliodon Simulator and the Solar Heating Simulator, provide students with real-time feedback about the solar performance of their designs (see Figure 1 for the design template and the features).



**Figure 1.** a) the design template; b) the Heliodon Simulator shows the sun path at the given location and time; c) the Solar Heating Simulator shows the heat map of daily solar radiation on the surfaces of buildings.

## Methods

Sixty-four high school students (9<sup>th</sup> graders) in Massachusetts, USA participated in the study. They used laptop computers to run Energy3D and worked individually on the Solar Urban Design Challenge for seven instructional periods (approximately 45 minutes per period). Energy3D is capable of automatically log what students do (actions), make (artifacts), and say (articulations) to provide fine-grained process data for assessments. An artifact folder typically contains 400 intermediate files and an action file typically contains 3,000-5,000 lines of event data. To analyze this sheer volume of data, a visual analytics program based on CPA

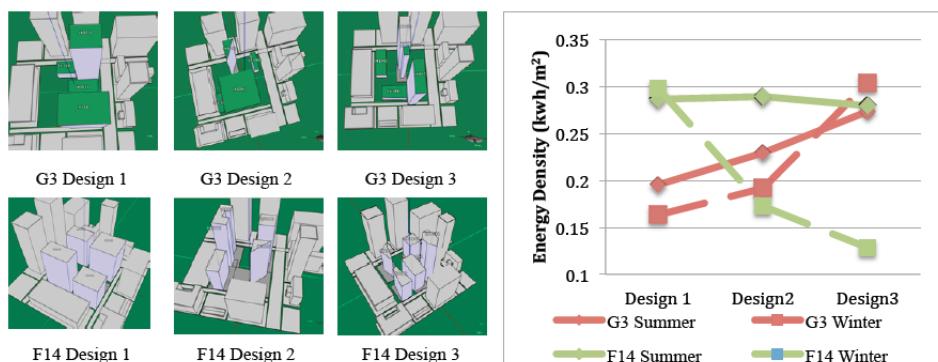
was written to automatically process the students' design actions and artifacts and rapidly visualize the results with graphs.

## Finding 1: Detecting Fixation and Iteration through Analyzing Design Behavior

Energy3D logs the timestamp, type, target, and parameters of the actions performed by each student. We focused on two types of iterative actions that lead to changes in solar performance of the buildings: 1) revision action that alters an element of the construction such as moving and resizing building; 2) time switching action that changes the time and date set up in the system, e.g., changing the time to Dec. 30 12pm. The CPA program can automatically calculate the percentage of these iterative behaviors. Dependent procedures such as quartile split can detect students who made fewer iterative actions. As an example, student G15 completed the design challenge with 2867 actions in total, among which 72 actions (2.51%) switched the seasons from winter to summer or vice versa and no actions moved or resized buildings. G15 probably has experienced premature fixation and her design likely would result in poor solar performance.

## Finding 2: Detecting Fixation and Iteration through Analyzing Artifact Performance

Another way to detect design fixation is through examining the solar performances of students' designs. CPA program automatically calculates the average daily solar energy density ( $\rho$ ) over the new construction. Naturally  $\rho$  is low in the winter and high in the summer for buildings in the northern hemisphere. In solar urban design, a design with optimal solar performance should receive maximal daily sunlight in the winter and minimal daily sunlight in the summer. Therefore, the difference between  $\rho$  in the winter and in the summer ( $\Delta\rho$ ) should be smaller in a good design than that in a bad design. Further, we consider solar performance as an indicator of design iteration because it is hardly possible for a student to complete a design with small  $\Delta\rho$  without iterations. The smaller  $\Delta\rho$  is, the more iterative cycles the students may have gone through. To illustrate this, Figure 2 shows the intermediate designs and the energy densities completed by two students, G3 and F14. As they progressed in the project, the  $\Delta\rho$  of G3's designs became smaller whereas that of F14's designs became larger. G3 probably has completed multiple cycles of iterations during the design project whereas F14 has experienced design fixation.



**Figure 2.** The intermediate designs completed by G3 and F14 and the daily energy density of the designs in winter and summer.

## Conclusion

Based on using CPA to analyze student process data during an engineering design project, the iterative cycles of design can be studied. This allows researchers and teachers to determine the degree of iteration and fixation of student design processes. Future work will explore what interventions would be effective to promote iterations.

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# **Enculturation: Contemporary Use in the Learning Sciences from a Historical Perspective**

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**Abstract:** We are working on an extended literature review to create a useful framework that elucidates the complex process of enculturation for the learning sciences. The purpose of this poster is to present our progress based upon issues and dilemmas that have come up in disciplines that have examined enculturation, with the goal of applying them to educational contexts. Such a framework can inform current learning sciences researchers as they appropriate this fundamental learning concept.

## **Background**

Enculturation is one of the foremost constructs describing how cultures evolve over time, from generation to generation. Since the mid-twentieth century, it has had significance in anthropology and sociology, where it was conceived. Despite its widespread use and obvious importance as a construct, or perhaps because of it, there are multitudes of definitions describing how the process works. It is clearly complex and has conceptual ambiguity (Shimahara, 1970).

Along with the impact of Vygotskian thought, which is the basis of the recognition of socio-cultural processes in learning (Wertsch, 1985), the learning sciences field emerged in the early 1990's. Innovative ways to view learning that took into consideration a community perspective (Brown & Campione, 1994; Lave & Wegner, 1999; Scardamalia & Bereiter, 1994) became new focuses in educational discourse. Fundamental behind many of these ideas was the view of learning from a metaphor of participation (Rogoff, 1994), showing that the learning sciences had adopted enculturation as a key concept (Brown, Collins, & DuGuid, 1989).

While enculturation has been widely accepted within the learning sciences at a macro-level, the conceptual ambiguity that it carried from other disciplines has still not been adequately theorized in educational settings. Recognizing that the enculturation process, on a micro-level, has unique characteristics within learning environments compared with the culture-at-large, the learning sciences community can benefit a great deal by refining the contemporary use of enculturation from a historical perspective. In this poster, we propose a preliminary perspective and inquiry process to investigate the contemporary use of the concept. Development of this framework can give consistency and clarity of use in the learning sciences given this conceptual ambiguity.

## **Guiding Questions**

We seek to develop a framework that can articulate the various perspectives that learning scientists have taken about the enculturation process at the micro-level. To do this, we ask the following questions:

- What issues surrounding the concept of enculturation existed or currently exist in other disciplines (e.g., sociology and anthropology)?
- How is this concept, as is used in the learning sciences, applied today?
- In what ways is enculturation different or the same whether in educational contexts or when considered from a broad cultural perspective?
- What framework can be applied to help learning scientists think about enculturation?

## **Inquiry Process**

We propose an extended inquiry process to answer our guiding questions. We will start by examining the conceptual ambiguities of enculturation from different disciplines. Thereafter, we will investigate how they are dealt with in the uniqueness of educational contexts. As part of the inquiry process, we will investigate the differences between related terms, such as acculturation and socialization. Similarly, we will address cases where enculturation is not explicitly defined, but is taken for granted (e.g., Heath, 1983). We will conclude our review with a synthesis of uses of enculturation within the learning sciences.

## **A Preliminary Perspective**

Our work thus far has led us to recognize several dimensions and open issues that are involved in conceptualizing the enculturation process. Table 1 summarizes various preliminary dimensions that we have appropriated from our review of relevant literature, with a lens on distinguishing between natural, professional, and educational settings.

**Table 1: Preliminary dimensions comparing enculturation in different disciplines and settings**

Dimension	Enculturation in everyday life	Enculturation in Educational settings	Enculturation in the workplace
Context	Everyday life (with the many cultural practices or behaviors, often contradictory)	Schools (depends upon clarity and consistency of school culture)	Work (depends upon clarity and unification of organizational culture)
Size	Culture or community (usually large)	Classroom or school community	Organization; workplace (usually small)
Age	Extends from day 1 to end of life.	Children (3-18) and adults (higher education and adult education)	Typically adult
Duration	Generation to generation	Semester, school year, several years in a school	Lifespan of a person's employment
Intentionality	Generally ambient	Designed	Generally ambient

In addition to these dimensions, there are also numerous open issues regarding the conceptual ambiguity of enculturation. We have identified three main analytical axes: a) uni-directionally versus bi-directionality; b) stable versus dynamic nature; c) descriptive versus prescriptive notions. Directionality refers to whether enculturation is viewed as a one-way street, from culture to individual, or if the individual also influences the culture. Stable versus dynamic refers to how and whether enculturation is conceptualized as something that undergoes change. Finally, descriptive versus prescriptive notions refers to whether enculturation is different in designed versus emergent settings.

We hope to further examine these issues and refine our preliminary framework as we continue with our extended literature review. This can ultimately contribute to how learning and becoming in practice, otherwise known as the process of enculturation, is theorized in the learning sciences.

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# How do Children Draw, Describe, and Gesture about Motion?

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**Abstract:** Grade 3 and 4 children ( $n = 19$ ) created “motion maps” (including both static and dynamic representations) that could be used to find a hidden object. Their drawing, oral description, and gestures used while describing, as well as the evaluation of the motion maps by their teacher were analyzed. Results suggest differences between lower and higher achieving children in the production of all the coding categories and in their conceptualizations of large-scale space.

## Introduction

Maps assist children in developing conceptual understandings of small- and large-scale spaces (Uttal, 2000). Children’s ability to use and to interpret maps in small- and large-scale spaces increases with age and this has been proposed to be related to increased experience with maps, encoding experiences, broader environmental experiences, and conceptual changes related to abstraction of space (Clements, 2004, p. 280; Piaget, Inhelder, & Szeminska, 1960). Studies have predominantly focused on children’s ability to use maps (i.e., navigation) or to interpret maps (Frick & Newcombe, 2012; Uttal, 2000). Less prevalent are studies that explore children’s ability to depict and to explain symbol-to-referent relations in 2-D representations that involve motion. Such studies may contribute understanding into the challenges that children face when asked to interpret and use maps.

In this research, we examined how children aged 8-9 years depict, describe, and gesture about symbol-to-referent relations in drawings (i.e., on an iPad) that also involve motion in what we refer to and describe shortly as “motion maps.” For the purpose of this research, motion in children’s drawings is understood as static representations of geometry (e.g., translations, rotations, symmetries, dilations, etc.) that reflect changes in one or more objects’ spatial and geometric identities (i.e., initial location and properties).

The question guiding our research was: *How do children depict, describe, and gesture about motion in their drawing of motion maps?* Our central premise guiding this research was that in order for children to effectively interpret and use maps, they must be able to create maps and to conceptualize and engage in motor actions that align with topographical representations within the map. The inclusion of motion elements in maps may force a child’s conceptual model to include elements of dynamic geometry that may facilitate increased ability to discriminate between locations in space and scale by having to think and plan for the object’s movement across space.

## Methods

In total, 19 children (girls  $n = 11$ , boys  $n = 8$ ) who had a mean age of 8.97 years ( $SD = 0.71$ ) participated in this research. As part of a culminating summative task to a transformational geometry unit of study, children were asked to create a drawing referred to as motion maps which are two-dimensional representations of space and contain objects that may depict motion (e.g., arrows). The children had the option of creating the motion maps on chart-sized paper (84 cm by 63 cm) or using drawing software on their iPads (paper  $n = 13$ , iPad  $n = 6$ ). Paper motion maps were captured to iPads by cameras on the iPads. The motion maps children created digitally were “locked” so that children were not able to manipulate the objects in them after they were captured to their iPads. Children were asked to verbally explain their motion maps. The verbal explanations, along with the motion maps, were captured by screencasting (i.e., image and audio narration) on iPads positioned on stand about 30 cm from the child so that the child’s hands were free. To capture the gestures, the children were simultaneously videotaped by the second author using a digital video camera on a stationary tripod.

Parameters of the task required that children construct motion maps that could guide a peer or an avatar of them to a hidden object (i.e., school mascot) somewhere in the school. The motion maps were to include one or more objects represented as geometrical shapes which moved across at least two distances (e.g., Point A to point B and then Point B to C) and to change shape either in scale or in orientation (e.g., dilate, rotate, reflect). The task was considered a large-scale spatial task because children could not see the whole space of interest at once (Quaiser-Pohl, Lehmann, & Eid, 2004). Objects in the motion maps could not be moved but the avatar could be moved.

The motion maps were assessed by the teacher (second author) using levels one, two, three and four, with four being the highest and one being the lowest level. Two curriculum expectations were addressed in the task considering both the drawing and the verbal explanation. A level of achievement was given for the drawing component and the verbal component, and then an overall level was computed based on the mean of the other

two levels rounded up. Coding of the objects in the motion maps, the verbal descriptions, and the gestures were then described in terms of whether they represented *static* or *dynamic* properties of the motion map (Uttal, 2013). Göksun, Goldin-Meadow, Newcombe, and Shipley's (2013) coding scheme related to the study on gesture in mental rotation tasks was also adapted for the coding of the gestures. There were two components to the coding of the gestures: (1) actual gesture (pointing and iconic), and (2) static or dynamic aspects of the motion map. In total, 25% of the transcriptions, coding, and assessments were done twice with discrepancies discussed and then resolved between coders. Descriptive statistics and non-parametric measures of differences between groups were computed using the Mann-Whitney U test. We make the distinction in the reporting of our results between "high" and "low" achievers and "higher" and "lower" achievement. High achievers refer to the total group of children achieving overall levels three or four. Low achievers refer to the total group of children achieving overall levels of one or two. Higher achievement refers to those children assessed in either levels three or four, and lower achievement may refer to those children who were assessed as either level one or two.

## Results

There were more static objects ( $n = 583$ ) than dynamic objects ( $n = 88$ ) in the drawings. Approximately 47% of the children received a level three or four for their drawings on the drawing component of the rubric. Those children that were the highest achieving, overall level four, produced less overall objects, static, and dynamic objects than those in levels two and three. These students showed efficiency and also a higher degree of effectiveness in their depictions.

There were more dynamic verbal descriptions ( $n = 186$ ) than there were static verbal descriptions ( $n = 84$ ). Approximately 26% of the children received a level three or four for their verbal descriptions on the verbal component of the rubric. Highest achieving children produced the least amount of verbalizations were able to communicate their ideas more efficiently using less verbal descriptions.

Children produced few gestures when describing their motion maps. High achieving children produced more overall gestures ( $n = 40$ ), compared to low achieving children ( $n = 31$ ). There were more static-type gestures ( $n = 51$ ) than there were dynamic gestures ( $n = 20$ ).

Based on the overall assessment (mean of verbal and drawing component of the rubric) there were 11 high achievers (58%) and eight low achievers (42%). Using the Mann-Whitney U test, statistically significant differences were found between high and low achievers in the production of dynamic objects ( $U = 142, \rho = .000$ ), total verbalizations ( $U = 523, \rho = .048$ ), dynamic verbal descriptions ( $U = 392, \rho = .001$ ), iconic-static gestures ( $U = 517, \rho = .005$ ), iconic-dynamic gestures ( $U = 550, \rho = .032$ ), and total production of dynamic gestures ( $U = 535, \rho = .040$ ). High achievers produced more of each of these codes.

## Conclusion

Results suggest that children were better at depicting motion in their motion maps than they were at describing motion verbally. Low achievers, compared to high achievers, produced very few objects and motion was particularly challenging for them to depict and describe. At the extreme levels, those children achieving an overall level four demonstrated what we refer to as *efficiency of representational relations*. They were able to use fewer verbal descriptions and fewer objects, but the most amounts of gestures, compared to those achieving an overall level of two or three, to convey their understanding. The results suggest that perhaps low achievers did not perceive the task to be large-scale, but rather a series of connected-smaller scale. The children's use of interconnected small-scale spaces to represent a larger-scale space could be used as a spring-board for developing large-scale spatial ability.

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# Design Principles for Science Laboratory Instruction Using Augmented Virtuality Technologies

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**Abstract:** This poster highlights design principles derived from piloting augmented virtuality laboratory (AVL) activities in secondary science classrooms. Our AVL activities leverage affordances of physical and virtual manipulatives through use of connected probeware and dynamic visualizations. To help students make connections among molecular and observable levels, we developed curricular materials with a scaffolded knowledge-integration approach. Observations, students' responses, and interview data were analyzed to extract design principles to inform future implementations of AVL and other mixed-reality approaches.

## Introduction

Science laboratory experiences allow students to interact directly or indirectly with the material world using scientific tools, methods, models, and theories (National Research Council [NRC], 2006). Laboratories typically incorporate physical experiences, whereby students can directly interact with scientific phenomena (i.e. using physical manipulatives; Gire et al., 2010), or virtual experiences, where dynamic visualizations are employed so that students can interact with scientific phenomena, especially phenomena that are not directly observable. Although physical laboratory experiences are widely used, physical labs do not always succeed in developing student understanding (Finklestein et al., 2005), as misunderstandings persist and are increasingly common with invisible phenomena (e.g. Eylon & Silberstein, 1987). Virtual laboratory experiences using software and simulations can benefit student learning (Honey & Hilton, 2011), yet even these types of experiences can lead students to emphasize superficial components of a phenomenon (Lowe, 2004) and fail to connect the virtual representation to scientific phenomena observed in the real-world.

Existing research indicates that sequential implementation of physical and virtual experiences is promising in terms of student learning (Gire et al., 2010, Zacharia & Olympiou, 2011). Other research demonstrates that connecting physical and virtual experiences has potential for learning (e.g. Moher, 2006). For example, Blikstein and Wilensky (2007) use connected sensors to real-time computer displays in a *bifocal modeling approach* to compare physical data to student-generated models side-by-side. Our work builds on these efforts and *simultaneously* combines probeware with dynamic molecular visualizations. Specifically, this poster presents findings from classroom tests of the Frame, an augmented virtual technology that uses physical sensors to drive a molecular simulation (Figure 1; Xie, 2012). With the Frame, students control a visualization of gas molecules in a chamber with physical manipulatives (scientific sensors). For example, students place jars filled with hot water near a temperature sensor to increase the temperature of the simulated gas. Additionally, they may physically push on the Frame that translates to the increased force on the virtual piston in the simulation. The simulation component of the frame offers a dynamic visualization through which students can also interact using a touch-screen interface. Simultaneous connection of physical and virtual manipulatives gives students the opportunity to link molecular and observable levels by manipulating physical objects and seeing resulting molecular behavior. This poster presents preliminary design principles for AVLs and aims to inform other mixed-reality approaches used in authentic classroom settings.

## Conceptual Framework and Methods

To help students build upon their own prior knowledge and make connections between ideas, we combined the Frame labs with a knowledge integration (KI) approach (Linn & Eylon, 2011). Specifically, we draw from scaffolded KI metaprinciples and KI patterns of *eliciting, adding, developing criteria for and reflecting upon ideas* to maximize student learning with the Frame labs.

To understand, utilize, and refine design principles concerning the implementation of AVL activities in secondary science settings, we use a design-based research approach (The Design Based Research Collective, 2003). By conducting contextualized experiments in classrooms to test hypotheses regarding learning outcomes, we aim for the systematic design of principles geared towards the development of effective classroom interventions.

We draw our design principles from four main cycles of implementations involving over 400 students in two different middle schools and three different high schools in the U.S. mid-Atlantic region. The first cycle consisted of usability studies in a high school classroom and clinical setting. The second cycle implemented AVLs with 6 teachers and 13 classes using a pre/post design. The third cycle involved 5 teachers and 10 classes comparing AVLs to traditional labs. The fourth cycle involved 4 teachers and 13 classes comparing AVLs to virtual labs. Data gathered included pre/post/delayed conceptual assessments, classroom observations and

videos, and student and teacher interviews. In each implementation, students completed the AVL following brief introductions by their physical science or chemistry teacher. Groups of 2-3 students worked together to complete the unit. Evaluation of several curricular approaches coupled with analysis of students' pre-/posttest data, curriculum responses, and interviews lead to the development of design principles for AVL.

## Preliminary Findings, Conclusions, and Implications

Design principles are still being refined from analysis of classroom runs. Preliminary design principles include:

*Help students distinguish ideas by problematizing content.* Students made more progress in developing molecular explanations of pressure when asked to distinguish their understanding of pressure through a more advanced topic of partial pressure as compared to directly developing an explanation of pressure. For example, when directly asked for a molecular explanation of pressure, many students' explanations of pressure failed to involve collision frequency with container walls or any molecular-level description. However, in other trials where students had to distinguish their understanding of pressure by figuring out the contributions of different kinds of gases, students provided more scientifically normative molecular explanations for the phenomenon.

*Explicit, intuitive correspondence between physical and virtual counterparts.* Students often made flawed connections or assumptions between the physical input and the visualization. For example, in the Frame, a real-life syringe controls the number of molecules in the simulation. Pushing in the syringe adds molecules and pulling out the syringe removes molecules. However, some students assumed that the volume in the physical syringe was directly connected to the volume of the virtual container. Similarly, some students believed that the visualization literally depicted the hot and cold jars that were used to control the temperature of the simulation. Designers of mixed-reality technologies need to pay special attention to the kinds of ideas that students bring to both types of interactions.

*Encourage multiple simultaneous interactions, preferably "in competition".* During the first and second phases, students largely divided the work so that one person recorded observations and explanations while the other student interacted with the AVL. Little collaboration or group knowledge-building occurred. However, observations revealed that successful groups interacted with the AVL at the same time with "competing" inputs. For example, one student would control the force through the spring and another would control the number of molecules with the syringe, spurring meaningful conversations about the connections among these variables. In subsequent iterations, the curriculum was changed to encourage this kind of student interaction.

Our findings highlight the importance of iterative refinement of both technologies and supporting curricula. AVL is an emerging technological application in science classrooms, thus this work has implications regarding implementations of these types of mixed-reality experiences in authentic classroom settings.

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# The Role of Feedback in Interest Development in an Out-of-School Engineering Setting

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**Abstract** The poster describes work-in-progress on interest development in an out-of-school robotics competition. Hidi and Renninger's (2006) Four-Phase Model of Interest Development is used to develop an interest assessment, along with a field-based observation protocol. High school students ( $N = 150$ ) and their adult team leaders are drawn from 6 robotics clubs: Rookie v. veteran clubs, crossed with high, low, and mixed SES populations.

The need for increasing recruitment and retention of high quality entrants into the STEM workforce is well documented (National Academies Press, 2007). In order to meet this need, students must be encouraged and motivated at a relatively young age to enter the “pathways” into these fields, which will require (among other things) developing and maintaining interest in STEM areas from elementary and middle school, through high school and into post-secondary education (Katehi, Pearson & Federer, 2009). An increasingly sophisticated view of interest development is emerging among scholars, just as hands-on, competition-based clubs and afterschool programs designed to foster interest in STEM education and career pathways is proliferating.

This study focuses on students participating in the FIRST Robotics Competition (FRC), an out-of-school robotics competition that now involves approximately 250,000 high school students in the US. Studies of the impact of robotics clubs on interest and motivation have been mixed (NAE/NRC, 2014). However, Melchoir et al. (2005), in a study using interviews of alumni of the program, found FRC to have a high impact on choosing engineering as a college major. The Melchoir study recommends further investigation into the *initial interest* of FRC participants. This study will develop an interest assessment and a field-based observation protocol based on Hidi and Renninger's (2006) *Four-Phase Model of Interest Development (FPMID)* as its framework.

## Major Issues Addressed and Potential Significance of the Work

Our central research question is: Does receiving feedback appropriate to a student's phase of interest development help sustain or increase the student's interest over time? This investigation will document the nature of feedback club members receive over time. It will also provide a greater depth of understanding on how STEM interest develops *in situ*, by providing examples leaders can utilize. If FPMID has predictive validity, and the interest measurement tool reliably categorizes students in their current phase of interest, then a method of formative assessment for interest for team leaders would be proposed to best meet the developmental needs of their students. Thus, this inquiry addresses the need identified in the literature for understanding how interest is maintained once it is triggered (Renninger & Hidi, 2011), as well as testing the validity of the FPMID.

## Theoretical Framework

The FPMID identifies four progressive phases of interest: Triggered Situational, Maintained Situational, Emerging Individual, and Well-Developed Individual. It provides descriptive characteristics of students in each phase, as well as descriptions of the specific (ideal) feedback needs of learners in each of these phases. Previous research on effective student feedback sometimes uses a “one size fits all” approach by recommending feedback that will have positive results for *all* students. However, current research in interest development recognizes that feedback that may have positive results for one student, may be inappropriate for students at a different phase of interest, and can have a negative impact on later interest development (Renninger, 2010).

The Model is used to develop two methodological tools. The first tool, the phase of engineering interest survey is being developed as an instrument to reliably categorize students into one of four interest phases. Currently there are no tools to reliably measure phase of interest development in this model (Renninger & Hidi 2011), and there is a demonstrated need for this type of tool (Renninger & Hidi, 2011; NAE/NRC, 2014). The second tool is an observation protocol developed for field use among FRC sites. This will be used to document feedback that participants receive from their team leaders and peers before, during and after an FRC competition season, as well as each team member's participation. The observation protocol will independently assess students' interest through their participation. Combining field observations with survey responses allows for a level of validity assessment of the model.

## Method

Baseline interest will be assessed prior to the competition season using a 64-item Likert scale interest survey administered to 150 high school students from six Midwestern FRC teams representing high, low and mixed

socio-economic status populations, crossed with rookie and veteran (more than three years of experience) teams. Survey results will be coded to derive a score for each participant, in six categories of interest phase characteristics: basic interest, positive feelings, content engagement, use of feedback, independent questioning, and perseverance. Initial survey responses will be used to match participants with their baseline phase of interest development. Observational data will be collected during the first week of the FRC competition season to validate the student participant's phase of interest identified by the pre-competition survey.

Observational data will be collected during the remainder of the FRC season the team's regional competition through observations and audio recordings of team meetings. This includes five weeks of a "build season" where students work to design, create, test and improve a unique robot built for a novel game unveiled at the start of the season (e.g., during the 2012 season, robots competed for the most basketball shots in two minutes, and then cooperatively balancing on a bridge with other team's robots). Observations will be coded for instances of types of feedback received by participants during the season. For example, the FPMID describes those who have a "Level 3: Emerging Individual Interest" as needing feedback that "enables him/her to see how his/her goals were met." An observed instance of this type of feedback would be coded as "Level 3" feedback, and compared with the student's developmental needs.

Student participants will also be administered the interest measurement survey (post) after completion of the FRC season. Pre- and post-season survey scores will be compared to measure interest changes for individual student participants. According to our research hypothesis, a greater proportion of students who have their feedback needs met will maintain their current interest phase or move to a higher interest phase than those student participants who do not receive the appropriate feedback.

## Conclusions and Implications

According to FPMID, students in a particular phase of interest have specific feedback needs in order to maintain or increase their level of interest. The aim of this study is to explore the predictive validity of the model in an out-of-school STEM learning environment using survey responses and field-based observations across a set of students in rookie and veteran clubs that attract high, low or mixed SES participants. This work can potentially test the predictive validity, while producing exemplars of matched and mismatched feedback as it occurs *in situ*. This work can lead to empirically based principles for maintaining and increasing interest in STEM. It may contribute to the design of formative assessments of interest for STEM learning environments that may help promote young people's interest in STEM education and career pathways.

## Relevance to the Theme of the Conference

This study is relevant to the 2014 theme of the conference, "Learning and Becoming in Practice," because of its focus on interest development in an out-of-school robotics competition. FRC promotes learning by engaging students in the *practices* of engineering. Students work side by side with teachers, and engineering professionals and students, to develop a working robot to compete in a real contest. The impetus for studying interest development in this environment is to better understand how students choose to engage in STEM subjects and activities, and ultimately how they take on the practices and habits of mind that allow them to *become* quality professionals in a STEM field.

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# **Comprehension SEEDING: Providing Real-Time Formative Assessment to Enhance Classroom Discussion**

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**Abstract:** The Comprehension SEEDING intervention aims to improve classroom discussion by providing real-time formative feedback to teachers based on student answers to open-ended questions. Teachers pose questions using the SEEDING system, students type responses, and the system automatically groups the responses according to semantic similarity. We describe the three features of the Comprehension SEEDING intervention: Self-Explanation, Enhanced Discussion, and Inquiry Generation and how teachers can use the system to identify misconceptions and facilitate a class discussion.

## **Comprehension SEEDING**

Classroom response technologies, like clickers, can improve student learning and engagement by allowing all students, rather than only the few a teacher calls on, to answer and by giving teachers real-time formative feedback. Previous research on clickers has shown that they can be beneficial for enhancing student learning and engagement (Duncan, 2006; Fies & Marshall, 2006). However, there are limitations that may explain why small-scale efficacy tests for the use of the technology have seen mixed results (Bunce et al., 2006; Carnaghan & Webb, 2007; Duggan et al., 2007). Typically, in order to take advantage of the automatic scoring provided by clickers, teachers are restricted to asking multiple-choice questions. In our intervention, Comprehension SEEDING, we aim to replicate the engagement advantages attained through clickers while removing the limitations of the multiple-choice format through the development of a new classroom engagement technology that provides real-time formative feedback to teachers based on student replies. In our system, teachers pose a free-response question, students generate and type their answers using tablet computers, and the system automatically groups the student replies into clusters. While the teacher can also view student replies individually in real-time, providing individual feedback to students may be time consuming, so the clusters allow teachers to quickly determine the current overall status of the students' understanding.

The Comprehension SEEDING intervention consists of three distinct but related features that combine to create an enhanced learning environment for students and teachers. Each component is strongly grounded in cognitive science and learning sciences research. The three components are: self-explanation (SE), enhanced discussion (ED), and inquiry generation (InG). We review each component and highlight the theoretical learning advantages of using the Comprehension SEEDING intervention.

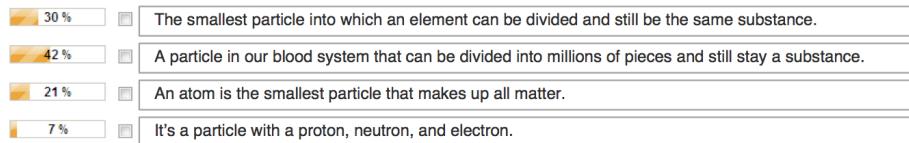
## **Self-Explanation**

In a Comprehension SEEDING classroom, a teacher poses a question and all students generate a response. Through the process of generating a reply and reflecting upon their answers, students are engaging in a form of self-explanation. In a traditional class discussion, only a handful of students are called upon to share; however, in a SEEDING class, all students must generate and input an answer to the question. We expect this feature to increase learning gains because all students are responding to the material and the process of generating an answer is more cognitively engaging than some students passively listening to other students' answers (Chi, 2009). Additionally, there is a large body of research that has demonstrated that learning increases when students engage in rationalizing or elaborating difficult concepts and relationships (*cf.* Wylie & Chi, 2014).

## **Enhanced Discussion**

After students respond, their answers are automatically clustered into semantically similar groups. The system then displays what it believes is the most representative answer from each cluster and the percent of student answers that fall within that cluster (see Figure 1). The teacher can choose to share these representative answers with the class as a basis for further discussion which could be a typical classroom discussion (without further using the system) or it could be guided by posing another question through the system. Teachers might ask students to rethink their answers in light of the discussion and to edit their original answer via the system or they might ask students to compare and contrast a pair of responses with a partner or in small groups.

**Question:** What is an atom?



**Figure 1.** The Enhanced Discussion component clusters student responses and displays representative answers from each of the four clusters as well as the percent of students whose answer falls within each cluster.

## Inquiry Generation

The final component of the Comprehension SEEDING intervention is the inquiry generation feature. This feature aims to support teachers in asking good follow-up questions, by automatically suggesting appropriate questions based on student replies. Previous research indicates that teaching good question asking skills encourages the listener to consider such questions while reading or contemplating subject matter and results in robust comprehension improvements (Singer & Donlan, 1982; Palincsar & Brown, 1984; King, 1990). We aim to support teachers and students by modeling deep reasoning questions within the system. For example, if a teacher asks, “What is matter?” as an initiating question, the system might suggest follow-up questions such as: “What is the difference between a solid, a liquid, and a gas?” or “What is the difference between *properties* of matter and *states* of matter?” The goal of this feature is to encourage teachers to facilitate deep discussions on the central topics in order to support learning.

## Discussion

In this paper, we present Comprehension SEEDING, an intervention designed to improve classroom discussion by increasing student engagement and providing immediate formative feedback to teachers. We discuss the three components (self-explanation, enhanced discussion, and inquiry generation), and the theories underlying them. Future plans include the effects of student learning and classroom discussion quality in a yearlong classroom pilot study.

## Acknowledgements

The research reported here was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305A120808 to the University of North Texas. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.

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# **Conditions for Successful Learning-by-Teaching: Lessons Learned in Training Prospective Science Teachers**

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**Abstract:** Learning in the 21<sup>st</sup> century where knowledge is constantly changing, requires the use of strategies that create knowledge building communities (Bielaczyc, Paik & Ow, 2012). *Learning-by-teaching* is one such strategy. This entails forming students' groups of enquiry, who come to discuss their research findings with the whole class (learning forums), to encourage the building of shared knowledge. This poster uses quasi-experimental method to investigate the change in the performance of teacher-trainees when using *learning-by-teaching* strategy, after using non-*learning-by-teaching* strategies. The poster also explores students' perceptions on their use of the pedagogic strategy, in order to illuminate the conditions suitable for successful implementation of method. Three cohorts of students participate in the study over three years. Findings indicate that the strategy succeeds when students' motivation is high, resources are adequate, and timely corrective feedback is provided.

In classes where *Learning-by-teaching* is used, tutors divide students into groups consisting of about three to eight students. Each group is given its own specific learning task which they research about, discuss and make preparations to teach the rest of the class. These learning tasks may be given as home work or (in the case of lower classes) could be given during the lesson. Therefore, each group designs its own ways and pedagogic strategies of imparting the knowledge to other students( Skinner,2006). After each group has taught, a learning forum, where corrections, comments, additions and elaborations are made, is opened. The tutor (teacher) does not 'teach', but participates as a member of the forum, while also providing guidance and support to students as they teach each other (Martin, 2008). The support mainly comes through providing resources such as books, reference materials, and teaching-learning tools, including electronic and digital media tools.

The argument for the use of the strategy is that it recognises students' abilities and prior knowledge, which can become one of the most enabling and most powerful factors for motivation (Shor and Freire, 1987). It is also deemed to provide *collaborative-constructive* ways of knowing that tend to encourage self-management and self-monitoring, resulting in improved performance on educational objectives (Garrison, 1997; Kuusissari, 2013)). The promotion of 'talk' found in 'learning forums' and inquiry-group discussions, are viewed as ways of encouraging seamless knowledge creation in the communities of learning (Wenger,1998; Mitchell and Sackney, 2000) which could elevate interest, engagement and motivation to learn. This poster seeks to find if the *learning- by- teaching* can increase performance and, if so, under what conditions can this be possible.

## **Method**

Participants were three cohorts of student-teachers. The first cohort were 23 prospective secondary biological-science teachers. They did not use *learning-by-teaching* in the 1<sup>st</sup> course done in their 2<sup>nd</sup> year, but they used *learning-by-teaching* in the course learned in their final/third year of study. The second cohort were 53(later 52) prospective primary science teachers. They did not use *learning-by-teaching* in the course done in their first year, but used *learning-by-teaching* in their final/third year of study. The last cohort were 84 (later77) prospective primary science teachers. They partially used *learning-by-teaching* in the course done in their first year of study and wholly used *learning-by-teaching* in the course done in their final/third year of study). The overall end-of term performance of all these students in the courses were recorded and compared.

Table 1: Descriptions of the Three Groups of Participants

<b>Cohort</b>	<b>Characteristics of each Cohort of students</b>
1 <sup>st</sup> cohort	Prospective secondary biology teachers studying with fewer resources in 2 <sup>nd</sup> year, but more resources in 3 <sup>rd</sup> year. They had enough time for both courses and were 23 in both years.
2 <sup>nd</sup> Cohort	Prospective primary science teachers that had fewer resources in first year (were53), but more resources in 3 <sup>rd</sup> year (were 52). They had enough time for the courses in both years.
3 <sup>rd</sup> Cohort	Prospective primary science teachers with extremely scarce resources in 1 <sup>st</sup> year (were 84) and studied under severe time constraints. They studied with more resources in 3 <sup>rd</sup> year (were 77) and had more time for the course.

Data was also collected from all the participants, using end-of-course evaluation questionnaires. The questionnaires were meant to find responses pertaining to the strengths and weaknesses of strategies and

resources used, as well as proposing improvements in the delivery of each course. The responses were coded and analysed qualitatively to find conditions leading to successful use of *learning-by-teaching* method.

## Findings

The graphs below shows number of students and their overall course marks obtained, using *learning-by-teaching* & when not using *learning-by-teaching*.

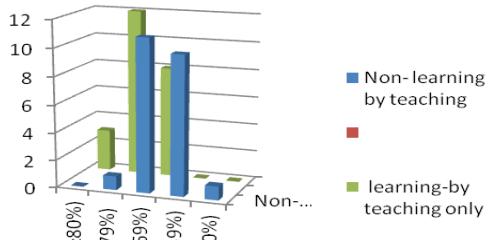


Figure 1. Marks obtained by 1<sup>st</sup> cohort

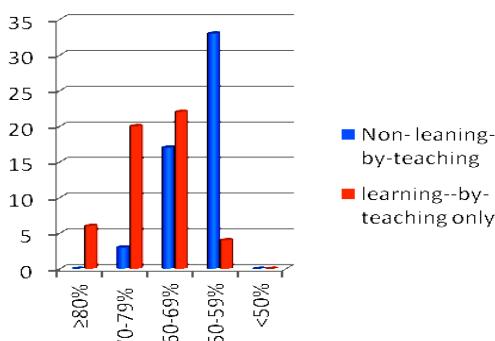


Figure 2. Marks obtained by 2<sup>nd</sup> cohort

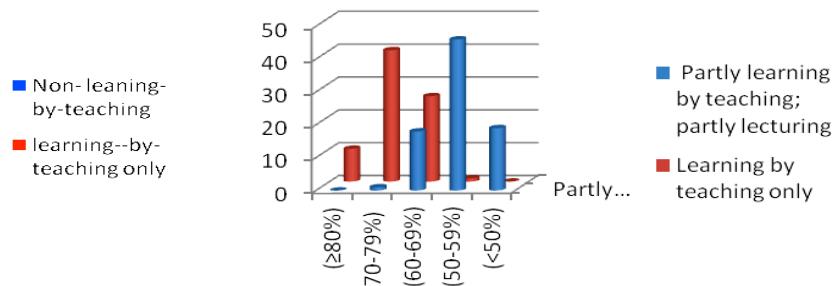


Figure 3. Marks obtained by 3<sup>rd</sup> cohort

## Analysis and Discussion

The performance outcomes of all the three cohorts indicate that there was a general improvement when each group used *learning-by-teaching*. However, these results could not be very conclusive as there could be other factors that could have led to improved performance, such as the experience of learners and the content of the course. More controlled and stricter experiments are needed to draw more accurate conclusions. Nevertheless, *learning-by-teaching* appears to be a promising strategy and further investigation are needed. The findings emanating from the analysis of the questionnaires confirm *learning-by-teaching* as a worthy learning strategy which needs more exploration and could yield better results if students understood the justification for its use, were motivated to learn that way, adequate resources were provided, there was enough time for researching/preparations and discussions, and timely corrective feedback was always given.

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# Learners' Intuitions about Geology

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**Abstract:** Many principles in geology are intuitive to geologists who already understand those principles, but little is known about learners' intuitions in geology. We apply existing theoretical machinery about learners' intuitions in physics to learners' intuitions in geology, and we present several examples of geology intuitions from teachers' reasoning about relative age relationships during field instruction. Implications are discussed for how to productively harness learners' intuitions in geoscience education.

## Learners' Intuitions from Physics Applied to Geology

In the learning sciences, there is a body of work investigating learners' productive use of intuitions in various STEM fields. Pratt and Noss (2002) presented a model of the microevolution of mathematical knowledge that included what they called naïve resources about randomness. Talmi (1988) focused on what he called "force dynamics" which are patterns and linguistic expressions for physical causes.

diSessa (1993) outlined a framework for learning physics that is based on students having a collection of intuitive knowledge about the physical world. These knowledge pieces, known as phenomenological primitives, *p-prims*, are thought to be the fundamental elements of the cognitive system. They are important for thinking and learning in physics. They are intuitions that can be accessed in both everyday life and the physics classroom. An example of one of these intuitions is *Ohm's p-prim*; more effort begets more results and more resistance gets less results. This is often simplified to "more is more". This intuition can be applied to many situations. For instance, to explain why one needs to push harder to move heavier objects, one cites more weight and more resistance, which implies more force is needed. Researchers have expanded this work to identify p-prim type intuitions in other STEM areas. For example, Lewis (2012) identified intuitions relevant to programming in computer science. Through a larger project investigating teacher's learning about topics in bedrock geology we are beginning to identify geology intuitions that may function similar to p-prims observed in physics. Extending work in physics education to geology education is reasonable because we would expect intuitions about the physical world to cross discipline boundaries.

Many fundamental principles in geology, such as the principle of original horizontality, which states that layers of sediment are deposited in horizontal layers due to gravity, are thought to be intuitive among geologists. This is not surprising as geology developed as an interpretative science from scientists carefully observing the natural world, intuiting how features arose. As observations of the natural world hold a prominent role in geology, learning in field environments has been key in geology curricula. Recently, Mogk and Goodwin (2012) reviewed the goals and attributes of field instruction and discussed gains from field instruction in terms of embodiment, creation and use of inscriptions, and initiation into communities of practices. They described the arc of field instruction as new geologists learn the practices of experts.

Here we connect intuitions about geological principles to research on intuitions in physics. We argue that in some cases learners use these principles in ways similar to how p-prims are used when learning physics. We illustrate this argument with excerpts from data of teachers discussing the bedrock geology and glacial geology of the area.

## Data Collection and Methodology to Identify Intuitions

The data were collected as part of a professional development workshop with 17 sixth-grade earth-science teachers. The goal of the workshop was to support teachers in becoming accustomed to modeling as described in the Framework for K-12 Science Education (NRC, 2012). The content focus was the geological history of the Schoodic Peninsula in Acadia National Park. During the workshop, teachers were engaged in fieldwork where they made a series of observations, drew surface and cross-sectional maps of the bedrock and surface features at three different locations while learning about important geological principles. Using these data, the teachers developed a series of increasingly sophisticated models of the geological history at three points in time (400 million years ago, 200 million years ago, and 20,000 years ago). Data consisted of video and audio recordings, drawings created by the teachers, and researchers' field notes. Initially we open coded the data. From these open codes we developed a set of focused codes including intuitive ideas relevant to geological principles.

As described in diSessa (1993) p-prims are easily recognized and self-explanatory. When someone uses a p-prim to reason no further explanation is needed, there is a "that's how things are" implication. When identifying p-prim-type intuitions it becomes important to look for instances where learners were satisfied and confident with their reasoning. Another way to identify p-prims is to look for cases where people use everyday

language. Finally, a useful heuristic is to look for commonalities across individuals or contexts to triangulate the p-prims across situations. These heuristics were applied to the current data corpus in conjunction with the existing list of p-prims (diSessa, 1993) to identify a series of candidate intuitions that are potentially p-prim-like.

## Data Analysis and Results

Sample data and results are presented in Table 1, and additional intuitions and data will be presented in the poster. Some of the geology intuitions listed are likely combinations of multiple p-prims-like pieces. This is not surprising given different intuitions often have a high likelihood of occurring in tandem (diSessa, 1993).

Table 1. Example intuitions in geology

Intuition Name	Theoretical Schematization of the Intuition	Proposed Idealized Geology Example	Data Excerpt
Conformity of Shape	A liquid takes the shape of a solid that is encasing it; the surrounding substance guides a flowing substance. Possibly an application of vacuum impels, which is schematized as emptiness requires filling (diSessa, 1993, p. 219).	As a hot liquid rock cools it takes the shape of a solid rock surrounding it resulting in the cooling rock's shape conforming to the surrounding rock's shape.	Teacher: It just makes sense to me that this other one came up and filled in the cracks... you can see what's holding this, I guess, it looks like it flowed, you know what I mean, flowed in that crack,...it seems like the black [rock] flowed around because when you look at the stripes going up, this one here it looks like it filled in a crack that was already in the granite.
Heavy things move downhill	Heavy things under large amounts of pressure will flow downhill.	A glacier feeling the effects of its own weight will flow downhill or down a path where there is least resistance.	Instructor: What causes the ice to flow? Why does it want to flow in the first place? Teacher: Cause, the weight of it pushing down on it, it's more fluid than solid...weight of it pushing down, it melts stuff at the bottom and goes where it can.
Springiness and rebounding	An object gives under pressure and then rebounds when the pressure is released. Possibly related to springiness and spring scale p-prims (diSessa, 1993).	Glaciers are heavy and will push down on the rocks, resulting in the compression of the bedrock below. When the glacier retreats the rocks will rebound.	Teacher: When the glaciers were here, it pushed the land down, and then when the glaciers melt the land comes back up, so maybe the cracks were formed that way. Instructor: So the pressure that came off when the glaciers went away. Alright. Teacher: I wonder if we are still rebounding, are we still rebounding from that glacier?

## Conclusion and Discussion

Learners accessed intuitions during geology field instruction that shared some resemblance with existing intuitions that are known to influence reasoning in physics. While this is not surprising because of the close theoretical relationship between geology and physics, it might be productive for education research and instruction in geology and other interpretative sciences to take into account learners' intuitions.

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## Acknowledgements

This work has been supported by NSF Grant no. DUE-0962805.

# **Development of Integrated Physics Identity through Physics Learning Assistant Experience**

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**Abstract:** We propose that connections between persistence, career trajectory, and participation in a Physics Learning Assistant (LA) program can be explained using the concept of the *community of practice* and its intimate relationship to *identity*. Preliminary analysis of written artifacts and interviews suggests that membership in the collaborative physics education community of practice created through the LA program increases LAs' engagement in negotiation of meaning in both instructor and student roles and strengthens their physics identity.

## **Introduction**

The Learning Assistant (LA) model, developed at the University of Colorado-Boulder and widely adopted (and adapted) at other institutions, provides undergraduate STEM students with coordinated experiences of content and curricular learning, teaching practice, and pedagogical coursework. LAs meet weekly with faculty to prepare for instruction, and facilitate discourse over fundamental disciplinary concepts in small-group instructional settings (see Otero, Pollock, & Finkelstein, 2010, for a detailed description). This model has been documented to lead to a number of positive effects on both LAs and students in LA-served courses, and to increase the number of STEM students choosing careers in teaching (Otero, Pollock, & Finkelstein, 2010). We analyze the experience of students in the Physics LA program at Texas State University in terms of the existing theoretical frameworks of *community of practice* (Lave & Wenger, 1991; Wenger, 1998) and *physics identity* (Hazari et al., 2010; Lock, Hazari, & Potvin, 2013), and explore the implications suggested by these theories for LA program adoption and adaptation. Regression models from studies by Hazari et al. (2010) and Lock, Hazari, and Potvin (2013) show that the physics identity construct strongly predicts intended choice of a career in physics; the goal of our current project is to understand the details of the impacts of participation in the LA experience on participants' practice and self-concept, in order to identify critical elements of LA program structure that positively influence physics identity and physics career intentions for students.

## **Theoretical Framework**

We briefly describe the two theories named above, and build a correspondence between factors in the physics identity framework and community of practice theory. This blended theory is used to analyze video of LA interviews and written artifacts for evidence of shifts in LA identity.

### **Identity in Practice**

Lave and Wenger describe participation in communities of practice and development of identity as deeply intertwined (Lave & Wenger, 1991; Wenger, 1998). Participation in a community of practice shapes and is shaped by the ways in which members of the community engage each other around their shared practice. Over time, the community develops a shared repertoire of resources for negotiating meaning, including language, stories, concepts, styles of interacting, and ways of accomplishing tasks. Identity, as shaped by this engagement in practice, is not an inherent or fixed quality of a person but rather a process of continuous re-negotiation – “a constant becoming” (Wenger, 1998, p. 154). Within this framework, Wenger (1998) identifies five characterizations of identity, four of which we find relevant to our current study: identity as *negotiated experience*, as *community membership*, as *learning trajectory*, and as *nexus of multi-membership*.

### **Physics Identity Self-Concept**

Hazari and colleagues (2010) describe and empirically validate a theoretical framework for physics identity composed of four dimensions: *personal interest*, *student performance*, *competence*, and *recognition by others*. Assessment of physics identity is based on self-report, e.g., the dimension *competence* can be described as “belief in ability to perform required physics tasks.” In a subsequent study, Lock, Hazari, & Potvin (2013) found that the dimensions of *performance* and *competence* formed a single factor; the theoretical framework was therefore simplified to three dimensions. We make use of this simplified framework in our analysis.

### **Relating Self-Concept and Practice**

In order to relate the empirically tested physics identity framework to concepts from the more general community of practice theory, we build a correspondence between factors. The link between the two should help the physics community create effective interventions that positively influence physics identity and physics

career intentions for students. The dimension of (self-reported) *recognition* in the physics identity framework, as measured through survey items such as “My physics teacher sees me as a physics person” (Lock, Hazari, & Potvin, 2013), describes an element of identity as *negotiated experience*: the process of making meaning from the encounters and experiences of participation in a community of practice. The physics identity dimension of *competence/performance* describes an aspect of *community membership*, which defines identity through the forms of competence developed and valued by participants in the community. Changes in identity over time build a sense of *trajectory*; identity as *learning trajectory* incorporates past identities and possible futures into making meaning of the present, encompassing the physics identity dimension of *personal interest*. Identity as *nexus of multimembership* is defined by the work of reconciling forms of membership in different communities. This blended identity theory is the basis for our analysis of the LA experience, described below.

## Methods

We examine written data sources and video of LA interviews for evidence of whether participation in the LA program has affected elements of LAs’ identity, and if so, in what ways and through what program elements. Written data are drawn from multiple sources, including teaching reflections, program applications, and written programmatic feedback. A subset of experienced LAs (N=7 out of 18 LAs with more than one semester in the program) participated in loosely-structured clinical interviews; interview subjects were selected to include diversity of major, gender, career plans, and length of experience in the LA program. The interview protocol included questions probing both self-perceptions (e.g., *What parts of being an LA are you particularly good at? Has being an LA made you more competent at other things besides teaching?*) and practice (e.g., *Do you use the Help Center to study or hang out? Do you interact differently with faculty since becoming an LA?*). Video data from interviews was examined using insight-oriented analysis (Scherr, 2009), in which the authors, informed by the theoretical framework described above, collaboratively analyzed video episodes that we identified as providing insight into the impact of the LA program on participants’ construction and perception of identity. Analysis of early interviews led to adjustments in the interview protocol based on emergent themes in the data.

## Preliminary Findings and Implications

Our preliminary analysis suggests that participation in the LA program impacts LAs in ways that support both stronger “physics student” identity and stronger “physics instructor” identity, and that these identities are reconciled into a coherent integrated physics identity. Increased comfort in interactions with peers, near-peers, and faculty seems to be an important component of this identity development and reconciliation, and is facilitated by the increased informal interactions between LAs, faculty, and peers provided by content preparation sessions and by the Physics Help Center (a resource for students staffed by LAs and near faculty offices). These interactions also seem to support an expansion of LAs’ perception of what constitutes competence: they learn to value and enjoy multiple ways of engaging in the physics community, including interactive examination of incorrect as well as correct reasoning, which re-purposes *saying wrong things* from a form of incompetence to an important component of competent engagement. Further work is planned to confirm these findings, including systematic coding analysis of an expanded corpus of interview data, and social network analysis of the physics student community.

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## Acknowledgments

This work and the Texas State University Physics Learning Assistant Program are supported in part by NSF grant DUE-1240036 and the Halliburton Foundation.

# Assessment Analytics in CSCL: Activity Theory Based Method

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**Abstract:** In this exploratory study, we present and apply an automated student participation analysis method derived from activity theory. We show how it can be used in a specific computer supported collaborative learning (CSCL) environment (Virtual Math Teams with Geogebra—VMTwG), and provide holistic analysis of individual student participation according to aggregate behavior, in order to inform teaching and assessment practices.

## Introduction

Automated assessment of student performance is a long hoped for, often strived for and probably distant objective for learning sciences research. A more pressing and achievable objective for learning analytics is to provide teachers with insights into student interactions. This work provides an activity theory-informed method for producing a holistic view of individual student participation in CSCL activities.

## Theoretical Framework: Activity theory

Activity theory is a social psychological and multidisciplinary theory that seeks to be naturalistic and offers a holistic framework for describing activities in practice while linking together individual and social behavior (Leont'ev & Aleksei, 1974). Engeström's (1999) model of the structure of an activity system includes the interacting components of subject, object, tools, division of labor, community, rules, and outcome (see Fig. 2).

The activity of learning is “the joint activity of a student, physical/symbolic tool(s), and another person(s) performing together as a working social system to achieve some outcome under constraints such as rules” (Basharina, 2007). Learning is reframed as social practice (rather than as merely the product of practice) (Engeström, 1999). In our CSCL learning assessment context, the outcome and process of this transformation may both be seen as learning. It is the sum of the system components and the tensions among them that make up the learning and influence the learning outcomes.

Current participation analysis methods only address part of the activity of the learning system. Activity theory helps us to address complex interactions in the environment, and to see into individual student interactions in a socio-technical environment. The activity system can be thought of as being built for each student, which allows us to highlight the learning of an individual student in collaborative group work.

## Case Description

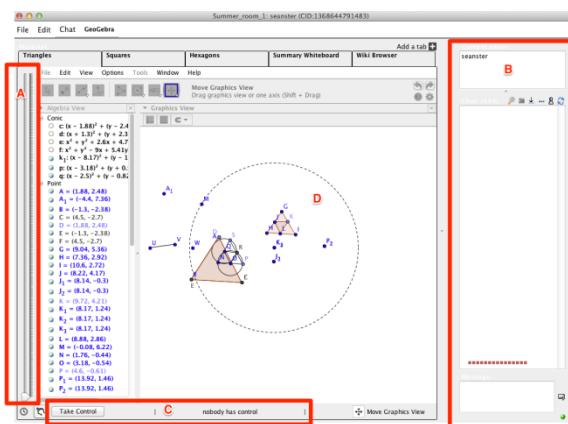


Figure 1. VMTwG of an Analytical Tool for collaborative Math Discourse.

In this study, we operationalize activity theory as a lens for making sense of electronic trace data from the synchronous math discourse software Virtual Math Teams (VMT). There are four main ways to participate in collaborative activities in VMT (see Figure 1). The time dimension (A in Figure 1) is provided by the VMT replayer bar (each action within VMT is logged with a timestamp). In the chat window (B), text is entered for direct textual communication among students. C and D are related to Geogebra actions. C is the “Take Control” button, while D is the GeoGebra window itself. In this figure, students are working to create an equilateral triangle within an equilateral triangle, and many approaches are being tried. This is an ordinary part of how VMT facilitates interactive problem solving discourse among teams. We collected log data in .txt format from five modules in a single course. The data centers on specific event types from the CSCL environment (VMT):

Awareness, Geogebra, System, Chat, and WhiteBoard (Wb). We process each event into four dimensions: individual, group, action constraints, and module set to facilitate measure construction.

## Measure Construction

*Subject:* When mapped to our log data, it represents all actions one student makes during the whole training under the individual modules, and is the sum of all actions under individual tasks (Figure 2).

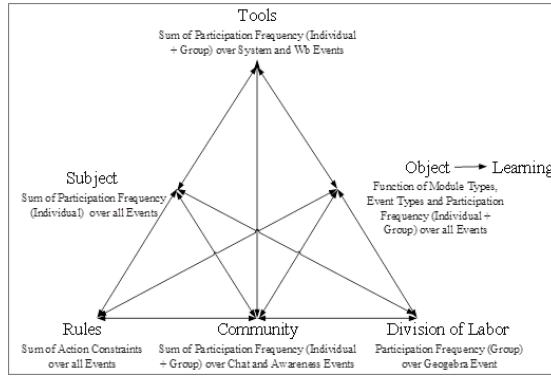


Figure 2. VMT data analysis using activity theory

*Rules:* Students have to perform actions that the VMT environment offers. Therefore, the Rules are reflected by the sum of actions the student uses across all the modules.

*Tools:* The tools are the System and Wb event types where the student's action for tool usage is registered. Thus, Tools are presented as the sum of participation frequency in System and Wb events.

*Community:* All the communications that help maintain the community structure. Community is presented as the sum of chat messages and awareness.

*Division of labor:* Contributions of the student made to the collaborative learning modules. The only concrete contribution to the geometry object construction is from the Geogebra dimension. Therefore, we use the student's participation in Geogebra events to represent the student's Division of Labor aspect.

*Object:* The CSCL activity is to achieve the object of a student's active involvement in the whole class. We incorporate the total of module types involved, frequency of participation and the number of event types.

## Results and Conclusion

Individual student participation in the course is represented as six dimension sets (after standardization) (see Table 1 as a *sample*). By investigation into those numbers, the teacher can provide specific advice to individual students. For example, if the value of a student in the Community dimension is very low, the teacher could suggest for the student to communicate more in the group. This methodology can be totally automated to be time efficient for teachers to use, and represents a unique, holistic, and theoretically informed approach to analyzing participation in group work.

Table 1: Sample Individual student participation model based on Activity Theory

Name	Subject	Rules	Tools	Community	Div. of Labor	Object
A	0.67	0.45	2.17	1.63	0.56	1.71
Q	1.14	0.06	0.42	1.62	0.12	2.35
:	:	:	:	:	:	:

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# What Does “Doing” Science Mean in the Elementary School Classroom? Bruno Latour, Inscriptional Transformations, and a New Look at Children’s Interactions with Phenomena

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**Abstract:** Redesigning the way children interact with phenomena is critical to supporting learning science’s core ideas through authentic scientific practices. Examining one design experiment through the lens of Latour, we analyze how 2<sup>nd</sup> and 3<sup>rd</sup> grade students interact with phenomena at a botanical garden and how their inscriptional transformations parallel Latour’s observations of scientists’ field research and laboratory interpretation. Our analysis suggests these practices support children understanding science’s “big ideas” as they learn in multiple contexts.

The NRC’s *Framework for K-12 Science Education* (2012) calls for integrating crosscutting concepts, core ideas and scientific practices. This conceptualization of science teaching represents a fundamentally different relationship between phenomena and science learning, engaging children in “doing” authentic science instead of enacting “hands-on” activities that lack deeper conceptual understanding. Given the central role that model building plays in scientists’ interaction with real world phenomena (Mayr, 1997; Giere, 1997), we focused our analysis on this interaction in the context of an elementary school design-based research project.

Latour’s (1990, 1999) “cascade of representation” framework is particularly fruitful for conceptualizing of the bidirectional connections between phenomena and model building. His research describes scientists’ interaction with phenomena, detailing: (a) how scientists use tools, inscriptions, and the transformation of inscriptions to make sense of complex phenomena; and (b) how this “cascade of representations” enables core aspects of phenomena to travel between disparate physical contexts. In our case study analysis of three lessons, we used Latour’s framework as an analytical tool for understanding a more synergistic relationship between elementary school science classrooms and phenomena. We examined how children’s interactions with phenomena at a botanical garden and their ensuing inscriptional transformations parallel Latour’s observations of scientists conducting field research and laboratory analysis. In detailing this parallel, we also explored how these practices simultaneously support children’s understanding of science’s core concepts and synergistically connect children’s science learning in varied contexts.

## Method

The case study analysis drew from a larger research project that studied 2<sup>nd</sup> and 3<sup>rd</sup> graders’ developing understanding of the conceptual underpinnings of evolution, in the context of their study of plants or animals (Metz, 2013; Metz et al., 2010). The project took place at a public school classroom and a summer school in an urban metropolitan area serving mostly low SES, ethnically diverse students. This case study was based on a sequence of three lessons, drawn from the 30-hour curriculum module. Data for this study includes: (1) students’ written and illustrated work, (2) teacher-generated visual artifacts of instruction, and (3) video recordings of the classroom and field-based instruction. Video recordings of children’s work in the three lessons were coded for the scientists’ inscriptional phases articulated by Latour. Then teacher actions were coded for support of students’ inscriptional transformations and interpretations. Students’ written and illustrated work and teacher-generated artifacts were examined for evidence of inscriptional transformations and abstraction of patterns.

## Results

Latour (1999) noted that scientists’ field research in the Amazon rainforest was motivated by a distinct question: Is the savannah advancing or retreating on the rainforest? To motivate the children’s field research at a botanical garden, the instructional module posed a “big” question - “How do differences in plants’ structures help them get what they need in different environments?” - and fostered initial puzzlement about plants’ form, function, and fit through class discussions and a variety of media. Building from these questions, students were introduced to tools that allowed them to query the botanical garden’s phenomena. The tools included a “sky cover instrument” to measure canopy coverage, a “green strip instrument” to measure plant chlorophyll concentration, and thermometers.

Latour observed scientists in the field using tools to generate initial inscriptions. Working in pairs at the botanical garden using selected tools, children transformed biological phenomena into words, tally marks, numbers, shaded squares, sketches, and photographs. In the rainforest and desert greenhouses, children recorded

environmental data (skycovers, humidity, and temperature) and plant data (green scale measurements, sketches and photographs of plants) using observation sheets and digital cameras.

Upon returning to the laboratory, Latour noted how scientists repeatedly transformed their field inscriptions to explore patterns in the data. Back in the classroom, children continued transforming their inscriptions through a “cascade of representations”, ultimately generating two aggregated data charts. In the photographs below (see Figure 1) showing part of one cascade, children used a green strip instrument to transform desert plants’ chlorophyll data into tally marks and later, each pairs’ chlorophyll data mode was used to construct a histogram. These charts, coupled with teacher support, were used to engage children in making inferences about the complex patterns among plants’ form, function, and the environment in which they live.

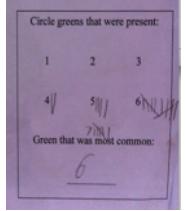
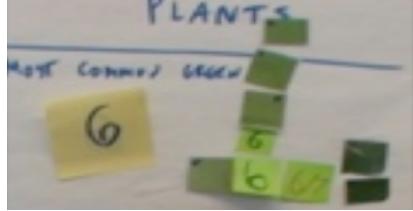
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Child using green strip instrument to quantify the amount of chlorophyll in desert plants at botanical garden	Children’s initial chlorophyll inscriptions	Chlorophyll data assembled into a histogram (part of larger aggregated data classroom chart with environmental and plant data)															

Figure 1. “Cascade of representation” of children’s chlorophyll data

Movement between objects and symbolic representations can be challenging for children and adults alike (Roth, Pozzer-Ardenghi & Yan, 2005). Two categories of teacher actions that supported this movement were identified: reversing the “cascade of representations” and mathematizing the data. Both teacher moves were crucial in facilitating students’ understanding of the “big ideas” and engagement with the practices that Latour describes. Through these parallel practices and specific teacher supports, children were aided in making numerous complex comparisons between the plant and environmental data in different biomes, connections that would be extremely challenging to make at the botanical gardens themselves or back in the classroom without these transformed inscriptional charts and teacher supports.

## Conclusions

Latour’s observations of scientists at work provides a powerful framework for conceptualizing elementary school science that embodies the knowledge-building practices of science and meaningfully integrates phenomena into science instruction. Analyses of children engaged in this module reveal rich interaction with phenomena and engagement with the representation transformation process, in many ways echoing the scientists’ activities documented by Latour. By providing children with multiple opportunities to interact directly with complex phenomena, inscribe their observations, and transform these inscriptions through a “cascade of representations” - both outside and inside the school walls - this module supports a more synergistic and epistemologically authentic relationship between phenomena and knowledge building in the elementary science classroom.

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# Cognitive Ethnographies of Heterogeneous Engineering Design

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**Abstract:** This is an empirical ethnographic study of how engineers in both undergraduate design courses and the professional workplace engage in engineering design. The findings suggest that the organizational contexts constitute processes of design differently, in ways that challenge the typical rhetoric of undergraduate education that project courses are intended to provide students with “real world” experience.

## Introduction

Design is “widely considered to be the central or distinguishing activity of engineering” (Dym, Agogino, Eris, Frey, & Leifer, 2005), and yet it remains an insufficiently researched and understood topic (Barley, 2004; Dym et al., 2005; Stevens, Johri, & O’Connor, 2013). From the perspective of engineering education, where a “disconnect” between professional engineering practices and school-based practices is an oft-discussed limitation, this sparseness of research on professional engineering design is both puzzling and troubling (Stevens et al., 2013). As Stevens et al. (2013) argue, trustworthy and specific representations of real engineering practices are necessary to inform attempts to prepare future engineers. The present study attempts to inform these efforts through comparative ethnographic research on design practices in the undergraduate curriculum and in the workplace.

## Theoretical Framework

The theoretical framework for examining practices of engineering design is provided by the notion of “heterogeneous engineering” (Law, 1987), which has been developed in Social Studies of Science and Technology as a way of countering a received “ideology of engineering” (Williams, 2002) that reduces engineering to the application of technical principles and processes in the service of solving technical problems. The notion of heterogeneous engineering, in contrast, sees engineers as “system builders” (Law, 1987, p. 112) who are involved in the active stabilization of systems that are composed of heterogeneous elements, both human and nonhuman. In this sense, what is being engineered is not just a technical object; rather, engineering *is* productive of objects, but also of persons, institutions, and everything that is part of the system that constitutes the object.

Suchman (2000) developed the notion of heterogeneous engineering in organizations, noting the implications of the perspective for learning and becoming. In the context of this project, the heterogeneous elements being coordinated can include the technical principles and processes held in high esteem within the technicist ideology of engineering. However, these principles and processes do not determine the course of engineering work; rather, they are flexibly adapted as resources in the flow of practice. They are, Suchman claims, appropriated in forms of “artful compliance” and “endless small forms of practical ‘subversion, taken up in the name of getting the work of the organization done” (p. 313). Suchman’s focus on the organizational context of the appropriation of the tools of technicist rationality points to the importance of understanding the organization, institutional framing of engineering activity. For the learning sciences, this focus calls for understanding notions of “authenticity” in ways that go beyond the modeling of epistemic practices of disciplines (Brown, Collins, & Duguid, 1989) and using these as the basis for enculturation into a profession or discipline.

## Methodology

The present study attends to the location of engineering design in different organizational settings, as a way of examining the nature of purported “disconnects” between professional engineering design practices and those taking place in the undergraduate curriculum. Our core methodology is that of “cognitive ethnography” (Hutchins, 1995), which examines how cognitive tasks, in our case design, are accomplished within “functional systems” (Hutchins, 1995) constituted of heterogeneous elements, both human and nonhuman. Our focus is on “how the work of the organization” (Suchman, 2000) gets done through the process of design. The research has three unique settings: a general engineering freshman design course, a senior mechanical engineering design course, and small to medium sized professional engineering companies in the same geographic region. Specifically from this project, we want to answer the following research questions: In what ways are there disconnects between the way engineering design is constructed in undergraduate courses compared to professional engineering design environments? What will make university design practices authentic to becoming a professional engineer?

This qualitative research study was approached with techniques for doing fieldwork in modern societies (Czarniawska, 2007). A variety of fieldwork methods, both direct and indirect, were used to capture all the elements of participants' activities in the design process. The observations include all parties that impact the design process, such as those organizing freshmen and senior design, employees in the machine shop, and clients. The researchers engaged in participant observations, while taking field notes and audio/video recording the meetings. The researchers followed the design teams through each step of the process. Additionally, all materials and artifacts that were produced by participants during their work were collected, such as copies of paper/electronic documents and photographs of temporary surfaces like whiteboards where participants used while working. There have been over 400 hours of observation and over 200 documents collected from following the design teams.

## Preliminary Findings

In this section, we report preliminary findings of the study; these findings will be developed as the study continues. Our initial findings are suggestive that the organizational contexts constitute processes of design differently, in ways that challenge the typical rhetoric of undergraduate education that project courses are intended to provide students with "real world" experience. Key among these findings are that, at the undergraduate level, abstracted technical descriptions of professional expertise serve a central role, in the form of, for example, design methodologies that are intended to serve as the basis for student work. Instructors of these courses—sometimes without substantive expertise in the design of "products"—rely on these epistemic forms to frame a learning trajectory through the course for students, and students' performance is thus graded on the basis of their proficiency with these technicist forms. Moreover, the organizational trajectory for these design courses appears to end with the semester; unlike sequenced courses in, for example, physics and calculus, design courses are not formally connected within the curriculum to any other courses. Finally, the "products" being produced—the contingently stabilized objects, in the heterogeneous engineering perspective—themselves may often have no trajectory: sometimes they are disposed of or disassembled for reuse of parts in future project classes, and are not always core aspect of the constitution of the organization. In contrast, at the professional level, trajectories are often organized around technical objects, and organizational and individual accomplishment is assessed on the basis of the success of these stabilized objects. Representations of expert performance, such as design methodologies, are not central aspects of the evaluation of performance, but rather are "subversively" used (Suchman, 2000) in order to get the work of the organization done.

## Significance

We expect the findings from this project to both contribute to our understanding of the nature of the structure and practice of engineering design and to have direct relevance to ongoing attempts to redesign the engineering education curricula, as well as add to conversations in the learning sciences on the nature of authentic practice.

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## Acknowledgements

This research was supported by the National Science Foundation (CMMI Grant No. 1355599).

# The Role of Stated Relationships in Detecting Contradictions Between Multiple Representations in Science

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**Abstract:** The interpretation and evaluation of data presented in multiple sources is vital to the investigation of scientific phenomena in disciplinary authentic ways. This study investigated 8<sup>th</sup> graders ( $N=119$ ) notice of contradictions between multiple representations (text and graph) when the relationship between variables was stated or inferred. Results suggest stating the relationship is related to identification of contradictions between representations. Results are discussed as they relate to the development of science disciplinary practices.

## Introduction

The ability to read and understand multiple representations is increasingly emphasized in educational research. This is especially true in the domain of science where being able to critically evaluate and compare multiple representations (e.g., text, table, graph, diagrams) is vital in order to investigate scientific phenomena in ways that are authentic to the practices of the domain (Ainsworth, 2008; Roth & Bowen, 2003; Wu & Krajcik, 2006). Accordingly, both science education professionals and educational standards emphasize the need for students to be able read and interpret data in different forms and use that information to be able to support and evaluate claims (Glazer, 2011; NGA & CCSSO, 2010). In order for students to critically evaluate a claim, it is important that they recognize discrepancies between the claim and the supporting data. However, research about the ways in which students interpret, evaluate and make decisions based on data presented in multiple forms is often disjointed and focuses primarily on texts. For example, there is evidence that students notice inconsistencies when reading totally verbal science texts and this is impacted by proximity of relevant information, source expertise and whether information is presented in single vs. multiple texts (Singer & Gagnon, 1999; Stadtler, Scharrer, Brummernhenrich & Bromme, 2013; Wiley & Myers, 2003). The degree to which students are capable of doing so when information is presented in visual versus verbal form is less clear. Accordingly, the current study investigated students' judgments of consistency between information presented in a verbal text and a graphic representation of that information. Specifically, we were interested in students' skills at recognizing whether a graph depicting a relationship provided in the verbal text did or did not match what was in the verbal text. We also manipulated whether this relationship was explicitly stated in the verbal text or had to be inferred by connecting information presented in the verbal text. We predicted that (a) students would be more likely to correctly identify a discrepancy between the graph and the text when the predicted relationship was explicitly stated than when it had to be inferred; and (b) descriptions of parts of the verbal text used to make the judgment would involve more parts of the verbal text when the relationship had to be inferred.

## Method

Participants in the study included 8<sup>th</sup> graders ( $N = 119$ ) attending 4 schools in the urban mid-west. We manipulated two variables within subjects: explicit versus inferred relationship and agreement between the graph and the verbal text (agrees vs. disagrees). Each participant saw 12 text/graph pairs (average number of words = 149.06), 4 of which were fillers and 8 of which were science topics (e.g., natural selection, the greenhouse effect, antibiotic resistance) Four sets of materials counterbalanced assignment of topic to the 4 explicitness x agreement conditions (2 topics per condition), and defined a between-subjects variable. Participants were asked to read each text, inspect the associated graph and answer two questions: 1) Using the information in the text, decide if this graph represents what we might expect to happen to [a variable in the specific topic] (response format: forced choice yes/no, and 2) What in the text did you use to make your decision? (response format: open-ended).

## Results

Forced choice yes/no responses were scored to indicate correct identification of text/graph contradiction or agreement. For example, if the graph contradicted the text and the participant indicated the graph contradicted the text they received a score of 1, yielding a maximum score of 2 per condition. Scores were analyzed using a 3-way mixed ANOVA with text explicitness and graph relationship as within-subjects factors and counterbalancing condition as a between subjects factor. Results show a main effect for text explicitness,  $F(1, 115) = 17.15, p < .01$ , partial  $\eta^2 = .13$ , such that scores were higher when the predicted relationship was stated ( $M = .74, SD = .43$ ) than when the predicted relationship had to be inferred ( $M = .61, SD = .48$ ). There was also

a main effect for graph relationship,  $F(1, 115) = 98.11, p < .01$ , partial  $\eta^2 = .46$ , such that the scores were higher when the graph agreed with the text ( $M = .82, SD = .38$ ) than when the graph disagreed with the text ( $M = .53, SD = .49$ ). There was no main effect for counterbalancing condition. There was a significant interaction between text explicitness and graph relationship,  $F(1, 115) = 4.49, p < .05$ , partial  $\eta^2 = .04$ . When the graph contradicted the text there was a difference between text explicitness,  $F(1, 118) = 16.62, p < .01$ , partial  $\eta^2 = .12$  such that the score was higher when the predicted relationship was stated ( $M = .63, SD = .39$ ) than when the predicted relationship had to be inferred ( $M = .43, SD = .37$ ). However, when the graph was consistent with the text there was no effect of text explicitness. Additionally, although there was a three-way interaction among explicitness, relationship and counterbalancing condition ( $F(3, 115) = 2.71, p = .05$ , partial  $\eta^2 = .07$ ), follow-up analyses indicated that the basic pattern of results was consistent for three of the four topic assignments to within-subjects condition. Open-ended responses to “what in the text did you use to make your decision?” were coded for number of different sentences indicated. Number of sentences cited was analyzed using a 2-way repeated measures ANOVA with text explicitness and graph agreement as within-subjects factors. Results indicated no main effects nor interactions,  $F's (1, 118) < 1$ . Additionally, for texts where the relationship was explicitly stated, a paired samples t-test indicated no difference in participants’ use of the stated relationship when the graph disagreed versus agreed with the verbal text,  $t(118) = 1.71, \text{NS}$ .

## **Discussion and Future Work**

The purpose of this study was to investigate students’ consistency judgments between information presented in a verbal text and a graphic representation when the relationship between variables was explicitly stated or had to be inferred using multiple pieces of information in the text. Results indicate that 8th graders can identify contradictions between verbal text and graph, but are more likely to do so when the predicted relationship is explicitly stated. The lower detection rate for contradictions when the relationship is not stated may indicate that students do not always generate the inferences most appropriate to identify a mis-match between claims and supporting graphical representations of data. Furthermore, the lack of differences for the number of sentences cited may indicate that students are not recognizing which parts of the text are most relevant to evaluate data about scientific claims. On the other hand, we are currently examining whether there are differences related to condition in *which* information is selected. These deeper analyses will inform efforts to build learning contexts in which students generate inferences from stated information about relationships among variables. Ultimately the goal is to develop supports for students to be able to engage in critical evaluation of data in a way that is authentic to the disciplinary practice. Plans for future work include further investigation of the influence of topic, prior knowledge and grade level.

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## **Acknowledgments**

The research reported here was supported, in part, by the Institute of Education Sciences, U.S. Department of Education, through Grant R305F100007 to University of Illinois at Chicago. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.

# Improving Online Collaboration by Fostering Norm-Oriented Content Based Knowledge Awareness

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**Abstract:** In transient online groups, fostering awareness about the content of the partners' knowledge from the outset has been shown to facilitate collaboration. A common problem, however, is lack of compatibility of individually designed knowledge representations. To address this problem, in the current study collaborators were given insight into each other's representation construction processes. As expected, the thus generated normalized representations facilitated the interaction.

## The Benefits and Challenges of Online Collaboration

The modern convenience of being able to work or learn collaboratively over long distances bears challenges as well as advantages. For example, according to the information sampling model (Stasser & Titus, 2003) groups tend to discuss information that is shared by all group members, whilst neglecting information that is unshared. It is easy to see then how in a transient group collaborating over long distance crucial information might be neglected and lost; the result being an inferior group effort. In addition, groups need time to establish who knows what in the group, i.e. to develop a transactive memory system (Wegner, 1986), so that in many cases the coordination of (mental) labor in the transient online group can be messy, in particular in the early phases of the collaboration.

## Content Based Knowledge Awareness

The Content based Knowledge Awareness approach (CoKA, formerly known as Knowledge and Information Awareness, KIA) has shown promise in ameliorating these problems (Engelmann, Tergan, & Hesse, 2010). By giving collaborators insight into each other's knowledge content, the approach aims to raise awareness of the entirety of knowledge available to the group so that the chances of unshared knowledge being neglected are reduced (Engelmann & Hesse, 2011). Moreover, through having insight into the collaborators' knowledge content (e.g. summarized in a diagram), group members have an easier time figuring out who knows what; a transactive memory system can thus be quickly established (Schreiber & Engelmann, 2010).

While several studies (Engelmann et al., 2010; Engelmann & Hesse, 2011; Schreiber & Engelmann, 2010) demonstrate the benefits of providing CoKA, there is the challenge that incompatibilities in knowledge representations tend to emerge when collaborators generate their knowledge summaries individually (e.g. Engelmann & Kolodziej, 2012). In order to circumvent this problem, in the current study group members were provided not only with insight into each other's knowledge but also into each other's knowledge representation generation process. It was anticipated that the resulting knowledge representations would be more compatible and effective in fostering CoKA. This in turn should promote effective collaboration.

## Method

The participants in this study were 120 (94 female, 36 male) University of Tuebingen students, mean age 23.7 ( $SD = 2.9$ ) who participated for payment. They were grouped into triads. Gender composition of the triads was controlled across conditions; aside from this, condition assignment was random.

Knowledge content representations were generated in the form of concept maps (Novak & Gowin, 1984). All participants received training in using CmapTools, an online tool for concept map creation. The collaborative task was to find the ideal pesticide and the ideal fertilizer for a fictitious type of spruce forest being threatened by several fictitious pests. This fictitious scenario was chosen to prevent a potential influence of the participants' prior knowledge. The scenario featured 13 concepts (e.g. building spruce, material bug) linked amongst each other by 30 relations (e.g. material bug severely damages the building spruce).

Each participant in a triad received a list of 12 sentences. These sentences represented that participant's expert knowledge on the issue. Overlaps in knowledge between participants were kept minimal. Each sentence described two concepts (out of the 13) and a link between them. If transformed into an appropriate concept map representation and combined with the expert knowledge of the other triad members the overall 36 sentences shared between the collaborators would reveal the ideal solution for the spruce forest problem.

During an individual phase, participants in the control condition were tasked with creating a concept map of their expert knowledge. Subsequently, in a collaborative phase, the participants had to pool their

individual knowledge, generating a joint concept map and solve the spruce forest problem. Importantly, at no point did the triad members in the control condition have access to the others' individual concept maps. In contrast, participants in the experimental condition were able to view the other group members' maps during the silent individual phase as well as later during the collaborative phase. They thus had CoKA.

## Results

As hypothesized the individual concept maps in the CoKA condition were more compatible than in the control condition. Three different measures corroborated this. In the CoKA condition individual group members had less variation in number of correctly depicted concept nodes (CoKA: 1.459, Control: 2.282) and less variation in number of correctly depicted relations (CoKA: 1.961, Control: 3.387). Both these differences were significant: *Welch's t* (29.63) = 2.12, *p* < .05 and *Welch's t* (27.40) = 2.87, *p* < .05, for number of correct concepts and number of correct relationships, respectively. The third measure was node centrality: In each concept map, a centrality rank was assigned to each concept node. The higher the number of relations emanating from a concept the higher its centrality rank. If participants in a group had similar standards for concept map creation, then they should have more agreement about the centrality of the concepts from the same category. Thus their centrality rankings should be correlated. Indeed, the centrality rankings within the CoKA group were more correlated than the centrality rankings within the control group (Average Z-standardized correlation coefficients for CoKA: 0.151, Control: 0.029). This difference was significant, *Welch's t* (36.12) = 5.07, *p* < .05.

Regarding the hypothesis that CoKA with prior insight into the group members' concept map construction process, it was found that the degree of variability of maps within the groups, as measured by the standard deviation in the number of correct nodes and the deviation in the number of correct relationships, is negatively related to group efficiency in the CoKA condition ( $r = -0.42$ ;  $p = .07$  and  $r = -0.50$ ;  $p < .05$ , for correct nodes and correct relationships, respectively). This means that groups in the CoKA condition found a correct solution faster when compatibility of their concept maps was high. No such relationship was found in the control condition ( $r = -0.23$ ; n.s. and  $r = -0.08$ ; n.s., for correct nodes and correct relationships, respectively).

## Discussion

The results of this study indicate that giving collaborators insight into each other's knowledge representation construction does indeed result in more compatible knowledge representations being created. This compatibility exceeds simple concept overlap and includes the actual form of the representations. While the data is still being analyzed, preliminary results indicate that having more compatible knowledge representations of the collaborators benefits group performance on the task. This is in line with previous results where participants were *a priori* provided with compatible knowledge representations and their task performance improved (e.g. Engelmann et al., 2010).

The results of this study further support the CoKA approach as a valid tool to facilitate transient interactions between spatially distributed collaborators. The insight into the partners' knowledge that collaborators using this approach gain at the outset of their interaction permits, amongst others things, a quick establishment of a transactive memory system (Schreiber & Engelmann, 2010). Having an overview of the knowledge available to the group also makes it less likely that unshared information will be ignored (Engelmann & Hesse, 2011). The present study further increases the ecological validity of the approach, showing that with insight into each other's knowledge representation creation, collaborators are capable of creating sufficiently compatible knowledge representations, which can foster CoKA and thus improve the collaborative effort.

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# Fostering Awareness Content Creation by Self-Determined Regulation

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**Abstract:** Prior studies have shown that without explicit instruction participants do not create complete awareness contents. Group awareness tools work implicitly. In this study it is investigated whether the construction of awareness contents can also be encouraged implicitly. Based on the self-determination theory it is expected that implicit regulation is more effective than explicit instruction. First results suggest that this is indeed the case.

## Introduction

Experts of different areas are needed to solve complex problems. Often, they can only communicate via internet due to time constraints and large distances. In this setting, misunderstandings can occur due to reduced context information. In order to prevent misunderstandings and communication problems, different tools were developed to foster *group awareness* that is defined as “consciousness and information of various aspects of the group and its members” (Gross, Stary, & Totter, 2005, p.327). A subtype of group awareness is *knowledge and information awareness* (KIA) that is defined as being informed on the collaborators’ knowledge and information underlying this knowledge (Engelmann & Hesse, 2010). Several studies have shown that groups provided with a KIA tool that visualizes the collaborators’ knowledge and information by digital concept maps perform better in a problem solving task (e.g. Engelmann & Hesse, 2010). In contrast to such studies in which the participants received individual concept maps pre-created by experts, Engelmann and Kolodziej (2012) examined what happens if group members create their individual concept maps on their own. It was shown a.o. that group members did not create complete maps resulting in a less effective KIA tool compared to that in studies with pre-created maps. The aim of the current study was to examine how team members can be motivated to create complete maps. Awareness approaches themselves work implicitly by providing task-relevant information without using explicit instruction. It can be assumed that the construction of awareness contents can also be encouraged implicitly. Explicit approaches, which directly instruct group members what to do, for example through collaborations scripts (e.g. Kollar, Fischer, & Hesse, 2006) already exist. In a study by Engelmann, Kolodziej, and Hesse (2014) explicit instruction was successful as all participants followed this instruction. However, implicit instructions should exceed explicit instructions: Providing prospective meta-knowledge to the participants is one example for an implicit instruction (Cress, 2005). According to Cress (2005), informing a person that an activity is important for the other team members increases the probability that the person performs this activity. Thus, arguably, emphasizing the importance of creating an individual map will lead to less disruptions of the task and to a higher map quality. Hence, in the current study, two different kinds of instruction are compared: an *explicit instruction* instructing the participants to first create an individual map of their own knowledge and information before they start with the collaboration as well as an *implicit instruction* in which the group members are not explicitly told what they should do but are informed about former study results which showed that groups with access to the concept maps of their team members performed better than groups without access to them. It was expected that both instructions would encourage the group members to start creating an individual map. However, according to the self-determination theory by Deci and Ryan (1993) it was assumed that the implicit instruction leads more often to finishing the maps, while the explicit instructions leads more often to discontinuing the map creation. Deci and Ryan differentiated several levels of extrinsic motivation by their degree of self-determination: For example, *external regulation* refers to people acting because they receive a reward or avoid punishment. *Introjected regulation* refers to behavior people show because otherwise they would feel anxiety or guilt or because they want to gain positive feelings like higher self-esteem. It was expected that the explicit instruction would evoke these less self-determined types of motivation. In *identified regulation* the goals of action are accepted as one’s own goals. It was expected that the implicit instruction would lead to this self-determined regulation type: As the participants were provided with information guiding their actions without receiving an explicit instruction, they should feel like they decided independently how to proceed. Self-determined forms of motivation reduce the probability to discontinue a task before completion (Vallerand & Bissonnette, 1992). Additionally, the performance in learning situations is improved and cognitive processing is deeper (Krapp, 1993). Therefore, it was expected that both instruction types encourage starting to create an individual map, but that the implicit instruction will more often lead to the completion of the maps.

## Methods

### Participants

93 participants (34 male) with an average age of 24 years ( $SD=3.49$ ) took part in the study. They were randomly assigned to the two conditions resulting in 15 explicit and 16 implicit groups (triads). There were no significant differences between the conditions w.r.t. gender composition ( $F<1$ ) and acquaintance of the members ( $F<1$ ).

### Material and Procedure

The criminal case the triads had to solve is based on a task by Schreiber and Engelmann (2010). First, the participants filled out a questionnaire for measuring control measure items. Then they practiced to create digital concept maps. In the main phase they were informed that they will assume the roles of detectives who together have to identify a murderer. The triad members each received a text document with unshared hints that had to be combined to solve the case. The members worked in separate workspaces. The members had to read a document containing all “their own” hints. Afterwards, each member had to indicate whom they suspected to be the murderer to differentiate between the individual and the collective solution. Then the members were motivated implicitly or explicitly to create their own concept map representing their individual knowledge and information as well as to start with the group discussion. In this collaborative phase, all participants could see their own working window, the working windows of their collaborators, and a group working window. The members could choose to either create their own individual maps in their own individual working window or to start working on a group concept map in the group window. In this phase they could communicate via headsets. They had 50 minutes to choose the murderer and give reasons why they suspect him/her. Afterwards, they filled out another questionnaire including questions concerning their motivation to create an individual concept map.

### Results and Discussion

All analyses were made on the group level as the individuals of a group were not independent of each other. First results showed that the members of the implicit groups needed significantly less time ( $M=34.7$  min) than members of the explicit groups ( $M=41.5$  min) to agree on their later solution ( $F(1,29)=5.6$ ;  $p<.05$ ). Furthermore the implicit groups needed significantly less time until they had written their final answer ( $F(1,29)=4.6$ ;  $p<0.05$ ). Furthermore, the members of the implicit groups perceived a stronger improvement of group collaboration over time than the explicit groups ( $F(1,29)=10.7$ ;  $p <.01$ ). These preliminary results point to the expectations that groups with implicit regulation performed better in the task in terms of time needed. Further analyses for example regarding the motivation of the participants and the quality of the individual maps are in progress.

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# Learning Integrated STEM Using Tangible Agent-Based Modeling

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**Abstract:** We investigate how the integration of visual agent-based programming and computationally augmented physical structures can support curricular integration across STEM domains for elementary and middle school students. We present ViMAP-Tangible, a learning environment, which integrates ultrasonic sensors with the ViMAP visual programming language using a distributed computation infrastructure, and report preliminary findings from studies conducted with 3<sup>rd</sup> - 5<sup>th</sup> grade students.

## Introduction and Background

Integrating agent-based programming and modeling with computationally augmented physical structures can support students in authentic scientific inquiry and allow students to develop and investigate their own scientific hypotheses (Blikstein & Wilensky, 2007). In a bifocal modeling approach, students connect computational behavior in virtual simulations with phenomena detected by physical sensors or produced in the physical world by motors or other output devices. In this paper, we develop this line of research further by investigating how agent-based visual programming can be seamlessly integrated with physical computation in order to support both learners self-expression and learning of canonical concepts and representational practices (e.g. programming, mathematical reasoning, and scientific modeling). We present an Integrated STEM (Sanders & Wells, 2006) curriculum, in which learners develop engineering concepts and practices, which in turn leverage the natural connections between two or more STEM domains. To support such a learning environment we use a technological infrastructure called ViMAP-Tangible (Sengupta, Krishnan & Wright, 2014). The central engineering practice that learners develop in our curriculum is User-centered design (UCD) (Norman, 1998). In this poster, we investigate how our pedagogical approach supports the development of specific forms of representational practices that are central to learning engineering, science and math. In particular, we present an illustrative case of how the distributed computational infrastructure, and the emphasis on User-centered design supported students' learning.

## The Learning Environment

Three key elements of ViMAP-Tangible are: (1) Computer Programming using ViMAP (Sengupta, Farris & Wright, 2012): Students generate algorithms by selecting commands from the library for each agent using a drag-and-drop interface in the ViMAP programming language; (2) Tangible and gestural representation of digital information: Students can use gestures or place physical structures in front the sensors to control different agent-variables (e.g., speed, color, position) within the ViMAP algorithm; (3) Simulation of agent behaviors: Students can dynamically visualize NetLogo (Wilensky, 1999) simulations of the behavior of each computational agent.

The learning activities consisted of three phases (Sengupta et al., 2014). During the first phase, students were introduced to agent based programming. During this phase, they learned to generate open and closed shapes (e.g. squares, circles, spirals) using ViMAP. In the second phase, students used these shapes as models of Newtonian mechanics (constant speed and acceleration). The third phase used an engineering design context in which students worked in dyads and were presented with a consequential design challenge. In both the studies, the goal during the third phase was for students to design a physical machine, linked to a ViMAP program, as well as accompanying user guides, using which *other* users – i.e., people besides the group members - would be able to accomplish specific tasks such as drawing geometric shapes using turtle graphics (see Figure 1). Initially, students were encouraged to designed machines so that they could be operated by meaningful, intuitive gestures in front of the sensors (i.e. raising and lowering of hand over the sensor would result in increase or decrease in readings). However, through user testing, they progressively developed more refined physical structures for greater reliability in the performance of their machines. For example, instead of using hand gestures directly in front of the distance sensor to generate a reading, students designed simple machines – such as Lego plates controlled by pulleys and wearable flat surfaces – in order to control the readings more reliably. These activities introduced students to User-Centered Design, which in turn encouraged and supported them to develop design thinking, and to be more articulate about the underlying rules of operation of their computational and physical artifacts.

## The Studies & Preliminary Findings

We conducted two pilot studies in a classroom on the campus of a large private university in a metropolitan city the mid-southern USA. Each study was conducted in the form of an enrichment program for elementary and middle school children, and classes met once a week (9:00 am to 11:30am) on six consecutive Saturday mornings. None of the students in this course had any prior programming experience. In Study 1, there were 16 participants, out of which eight students were in 4th grade and eight students were in 5th grade. In Study 2, there were 16 participants, out of which eight students were in 3rd grade, and eight were in 4th grade. The data for the cases were in the form of in-depth interviews with the participants, student work (ViMAP programs, written user guides, and physical artifacts), and field notes. Here, we briefly present a case from Study 2 that also illustrates some of the themes we found in Study 1. A detailed analysis of student work can be found in Sengupta et al. (2014).

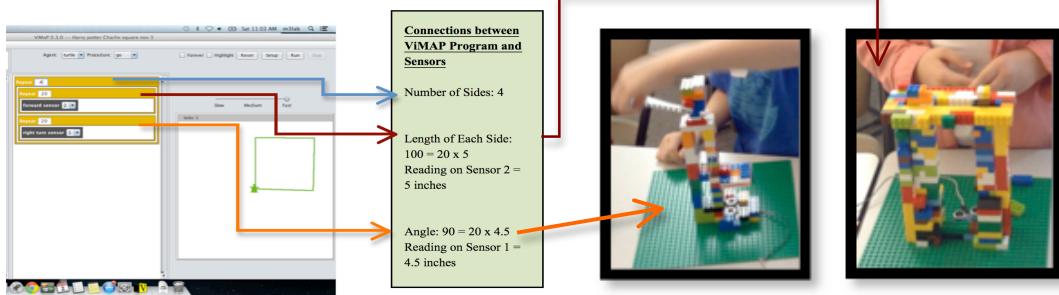


Figure 1. Chuck & Jerry's physical machines and their ViMAP program for generating a square

Across both the studies, we found that a) the distributed computing infrastructure resulted in creating positive interdependence (Antle & Wise, 2013) among students, as members of each group made coordinated, non-redundant contributions towards a common goal; and b) a focus on UCD resulted in students iteratively developing refined physical and computational representations towards their design objectives, which in turn resulted in deeper scientific and mathematical reasoning. For example, in Study 2, during Phase 3, a pair of students, Chuck and Jerry, built two separate machines, connected together by a ViMAP program (Figure 1). One machine consisted of a flat plate that could be lowered or raised above a distance sensor, using a pulley mechanism, in order to control the angular turn of the computational agent. The other machine also comprised of a flat plate, which could be lowered or raised above a distance sensor, using a manually operated crank lift, in order to control the speed of the computational agent. Both of these machines were communicating to the same ViMAP program (see Figure 1). In this program, students designed a nested loop in order to control the number of sides and angles, where the number of each loop was determined based on the relevant sensor reading, using multiplicative reasoning (explained in Figure 1). In addition to building these structures, the students created a set of rules that would provide the users instructions on how to use the physical setups to draw specific geometric shapes. As a result of user testing, these rules became more refined in order to facilitate better coordination users. The physical structures also improved in order to provide better control for users as they manipulated the flat plates. These observations suggest that UCD afforded two key benefits: first, UCD supported the development of design thinking; second, UCD grounded in an Integrated-STEM pedagogy supported learning through making and doing through an iterative process of designing, building, testing, revising and evaluating models.

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# **Linked Reading and Writing Using Wikilinking: Promoting Knowledge Building within Technology-Enhanced Classroom Learning Communities**

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**Abstract:** This poster describes and analyzes linked reading and writing through the use of Wikilinks to promote socio-constructivist learning within a technology-enhanced classroom learning community (TCLC). The course under research is a graduate course designed as a TCLC supported by a Wiki collaborative editing environment. We conduct a micro-analysis of data collected from the Wiki, classroom observations and interviews. We hope this study will contribute to understanding of knowledge building and design of future TCLCs.

## **Literature Review**

Classroom learning communities (Bielaczyc & Collins, 1999) may be supported by various social technologies. One such technology is an online Wiki collaborative editing environment. We are interested in learning about the unique features of Wiki in supporting meaningful socio-constructivist learning, in particular, individual and shared knowledge construction using linked reading and writing. Earlier work describes and advocates the use of Wiki to support collaborative learning in graduate statistics courses (Ben-Zvi, 2007), and in a CSCL course named “Challenges and Approaches to Technology-Enhanced Teaching and Learning” (CATELT) (Hod & Ben-Zvi, 2013; Konja & Ben-Zvi, 2008). CATELT is a Wiki-based blended course as a part of the Educational Technologies Graduate Program at the University of Haifa, Israel. The course was originally enacted in 2006 and has been taking place annually since.

The same Wiki learning environment has been used across all course generations (with some modifications) thus enabling each generation to build upon and advance the shared knowledge of the technology-enhanced classroom learning community (TCLC). Students in CATELT are of differing levels of expertise, however, most are still novices with regards to CSCL and TCLCs. In this poster, we present the early stages of research based on the 2013 iteration of CATELT, focusing on how using links within a Wiki promotes socio-constructivist learning.

## **Learning and Knowledge Building**

“Learning is an internal, unobservable process that results in changes of belief, attitude, or skill. Knowledge building, by contrast, results in the creation or modification of public knowledge—knowledge that lives ‘in the world’ and is available to be worked on and used by other people” (Scardamalia & Bereiter, 2003, p. 1372). Cress and Kimmerle (2008) have developed a model to build on this distinction of learning and knowledge building to better understand collaborative knowledge building with Wikis. Their model is based on Lunemann’s systemic approach and Piaget’s theory of equilibrium. Knowledge building is described as the processes within the Wiki social system, the cognitive processes of the learners, and the interplay between them. Two processes of individual learning: internal assimilation and internal accommodation, and two processes of collaborative knowledge building: external assimilation and external accommodation. The cognitive and social systems develop mutually, resulting in collaborative knowledge building.

## **Linking and Learning**

The constructivist paradigm sees learning as a process in which the learner is active in gathering and organizing information, processing it, connecting it to prior knowledge, providing interpretations and turning it from information to knowledge (Salomon, 2000). Information usually consists of distinct facts, concepts, ideas or procedures, and knowledge is seen as a web of connections between pieces of information. To engage in meaningful learning, a student must make links between pieces of information within one’s cognitive system.

Wiki, the web application, is also a web of connections between Wiki pages that are well interconnected by hyperlinks, and in this way represents the constructivist view of knowledge. Wikis use a simplified syntax for linking pages within Wiki environments, called “Wikilinks”, which is different from the syntax of external links, leading to web pages outside of the Wiki. When an internal Wikilink leads to a page that does not exist, it has a distinct visual appearance (e.g., red instead of blue). The Wiki promotes the creation of meaningful links between pages by making page link creation easy and intuitive. The Wiki also aims to involve the learner in an ongoing process of creation and collaboration that changes the website’s landscape (Leuf & Cunningham, 2001). These characteristics of Wiki make it a good choice as a learning platform in constructivist learning environments, such as TCLC’s.

In CATELT, learners are constantly engaged in creating new pages, improving existing pages, and adding links between pages. While doing so, the process of connection-making can become visible as they make these connections by adding Wikilinks. These Wikilinks are objects that can be reflected upon and used as a basis for deeper understanding. If we were to apply the model of Cress and Kimmerle (2008) to Wikilinking, then it can be viewed as an external process that can contribute directly to collaborative knowledge building. Similarly, browsing the Wiki can be viewed as an internal process of individual learning, which may indirectly contribute to knowledge building at a later stage, once learners externalize their new understandings.

## **Research Questions**

Based on the literature review and our deepening understanding of students' Wikilinking in CATELT (see preliminary findings), we propose to further study connected reading and writing. In particular, we plan to study the connections between Wikilinking and knowledge building within CATELT. Our primary research question is: *How do students' linking practices develop within a Wiki collaborative editing environment?* We ask the following sub-questions to answer our main question:

- What are students' Wikilinking practices?
- What changes in Wikilinking practices do novices make as they gain expertise in a Wiki-based collaborative learning environment?
- What do learners' Wikilinks practices indicate about their knowledge-building?

## **Methodology**

Data for this research is collected from classroom observations that are, video recorded, interviews with participants, and from students' activities on the online Wiki collaborative editing environment. The data is then analyzed using a microgenetic method to uncover processes and developments relevant to answering the research questions (Granott & Parziale, 2002).

## **Preliminary Findings**

From analyzing initial data from CATELT 2013, a few interesting observations can be made about the way learners used hyperlinks. First, novice learners hardly created new hyperlinks when they created pages in the Wiki. Second, the links made were typically external and not Wikilinks. This fact may provide information about learners' epistemologies, such as whether they consider the source of knowledge to be external, or created within a learning community through extended iterative constructivist processes. Third, there was a noticeable difference between the novices and the more expert learners in the TCLC. The latter made extensive use of hyperlinks in their page, used mainly internal Wikilinks and even created new Wiki pages and linked to them.

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# **Building A Framework for the Process of Crafting and Using Definitions**

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**Abstract:** I have built and will present an analytic framework for the process of crafting definitions for the purpose of classifying examples. I draw on data from undergraduate physical science students working to craft a definition of *threshold* for the purpose of helping younger people identify *thresholds* in the world. I present results around how definitional refinement begins and proceeds.

## **Major Issues Addressed and Potential Significance**

The process of crafting definitions is an important yet understudied part of professional practice. Research in STEM education that focuses on this process generally falls into two camps: existence proofs that students can productively engage in crafting particular definitions (Atkins and Salter, 2010; Swinyard 2011) and more general framework building (Nachlieli and Sfard, 2003; Zandieh and Rasmussen 2010). These two more general frameworks focus on opposite ends of the spectrum of the length of a defining activity. Nachlieli and Sfard's work on "the activity of defining" (AoD) is focused on shorter clarifying moves. Zandieh and Rasmussen examine multi-week curriculum and focus on "the role that defining can play in students' transition from less formal to more formal ways of reasoning" and build a Defining as a Mathematical Activity (DMA) framework.

The general framework that I will present is unique in two ways. First, with respect to length of the defining activity, my framework falls between AoD and DMA: I examine a two-hour long process in depth. This focus allows for additional insight into when and how definitional refinement occurs. Second, my framework building relies on data from physical-science college students working on crafting a definition for a science-related term while previous work on general frameworks has focused mainly on mathematics education. This paper will focus on the research question, "how does definitional refinement begin and proceed?" An analytic framework will be presented that will support researchers studying the process of crafting definitions.

## **Methodological Approach**

### **Data Collected: Workshops**

In developing a framework for the process of crafting definitions, I wanted to first see how college students might engage in the process on their own with minimal facilitator interaction. I designed, implemented, and video-taped workshops where participants (groups of three upper-division undergraduate physical science majors) attempted to meet the design goal of crafting a definition of *threshold* to support younger people in identifying *thresholds* in the world. After explaining this design task, I let them work uninterrupted for two hours, returning only twice to briefly ask them to tell me what they had been working on or to ask them about some examples that had led to debate in previous pilot workshops. After collecting and analyzing data from two workshops, I asked two additional participants to engage in the activity individually so that I could ask follow up questions and probe their thinking in more detail.

### **Analysis Methods**

The analytic framework I developed for the process of definitional refinement involves interplay between four main elements: the current state of the crafted definition, criteria for what makes a good definition, examples, and definitionally unarticulated knowledge (DUK). DUK is related to judgments that definers make about example categorization. These are judgments that have not been incorporated into their definitions per se..

This framework was developed through examining episodes of definitional refinement in the data, i.e. moments when participants changed words or phrases in their definition. The approach to naming important framework elements was top-down meets bottom-up. The research literature on crafting definitions and representations, related design tasks, suggested that criteria would be important to the process (Bowker and Star, 2000; Zandieh and Rasmussen 2010; diSessa et al., 1991). I developed a methodology to identify criteria in video data. After an initial viewing and content logging of the data (Jordan and Henderson, 1995), and through a process of naming important elements through analytic induction, it became clear that examples, the crafted definition itself, and DUK were central to definitional refinement. I developed a methodology to identify DUK as well, resulting in three important sub-categories of DUK. These framework elements supported the identification of a two-stage process present across many episodes of definitional refinement. This will be explicated in the results section.

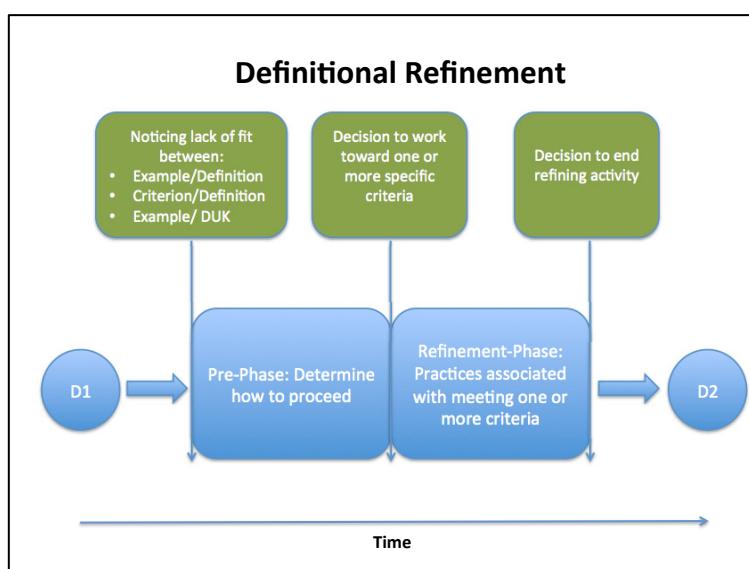
## Results

### Definitional Refinement Begins in One of Three Ways

Empirical analysis showed that definitional refinement began in one of three ways. Participants either noticed a lack of fit between (1) an example and their crafted definition, (2) their definition and a criterion for what their definition should achieve, or (3) an example and some definitionally unarticulated knowledge. In the case of (3), participants noted that an example did not seem to fit and would describe this lack of fit using words not found in their definition. They would then choose to incorporate these new words into the definition. For instance, one student noted that she found a particular example problematic because it did not seem to include a “build up.” This phrase was not found in her definition but was then added.

### Framework for How Definitional Refinement Proceeds

Another result of the empirical analysis is that definitional refinement proceeded roughly in two stages. After participants noticed a lack of fit between framework elements, there was an initial sense-making stage of understanding how important this lack of fit might be and deciding that it was worthwhile to work on. Participants then decided to work to meet one or more particular criteria. In making changes to the definition they almost always brought in further criteria to guide their work. This is outlined in the diagram, below:



**Figure 1.** Definitional refinement proceeds in two phases from initial definition D1 to final definition D2. The blue boxes denote the two stages of definitional refinement. The green boxes denote transition moments.

### Conclusion and Relevance to Conference Theme

With respect to the conference theme, this work examined college students engaged in a design task that is also a disciplinary practice: crafting definitions. The analytic framework provides support for researchers and educators in unpacking what is important to the process of crafting definitions. One limitation of this work is that the activity did not ask participants to compare their definition to other definitions. This would be an important additional source of definitional refinement to consider in future work.

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# Re-grow Your City: A NetLogo Curriculum Unit on Regional Development

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**Abstract:** This poster presents the design of an agent-based modeling activity for teaching regional development and social policy at the undergraduate level. Taking a Constructionist view of learning and design, it allows students to learn about the relationship between the emergence of particular socio-economic neighborhoods and the infrastructural design of cities, by ‘re-growing’ their own city.

## Mechanisms and Constructionism

Despite decades of social sciences *research* using agent-based modeling, its use in social sciences *education* is understudied. This poster presents a curriculum unit using agent-based modeling to support a mechanism-to-dynamic-focused, Constructionist approach to teaching social policy at the undergraduate level. In particular, this policy focuses on Regional Development, and on how social policies and infrastructural decisions can affect the socio-economic emergence of a city’s neighborhoods. Epstein (1999) famously said about agent-based modeling in social sciences that, “If you didn’t grow it, you didn’t explain it.” By deploying a NetLogo model, the unit allows students to change the infrastructural and zoning design of their city and to ‘re-grow’ their own city.

College students struggle with understanding how social policies and urban planning affect the racial and socio-economic composition of a city’s neighborhoods. This should be cause for alarm, because if even highly educated citizens are unable to reason cogently about the relationship between policy intervention and outcome, we run a serious risk of political inertia. Experimental research on policy learning suggests that knowledge and beliefs about policy issues are correlated, and that a mechanistic approach to explaining policy issues can strengthen both understanding of an issue, and support of policies to address it (Clark, Ranney & Felipe, 2013). This suggests that taking a mechanism-focused approach to teaching about the relationship between social policies and their outcomes may be productive in a social policy educational context. However, another line of research focusing on learners’ reasoning about complex systems (e.g. Wilensky & Resnick, 1999) suggests that even if learners understand each of the individual mechanisms of a system, they may still struggle with understanding the dynamic system-level outcomes. As a remedy, agent-based modeling has been used as educational tools for at least two decades, offering learners a ‘tool-to-think-with’ to cognitively offload their knowledge about individual mechanisms, and let the model show how they dynamically interact. Agent-based modeling has been used for education in STEM (Wilensky & Resnick, 1995; Jacobson & Wilensky, 2006). The present unit extends design and research experience from this work to education in social sciences.

Use of agent-based modeling in education has typically taken a Constructionist approach to learning and to the design of learning activities. Constructionism holds that learning happens best when learners construct external, shared, and personally meaningful artifacts (Harel & Papert, 1991; Papert, 1980). This unit implements these design principles by encouraging groups of students to redesign a city that they are already familiar with. Further, by drawing on a familiar city, students may activate educationally productive epistemological resources relating to their personal experiences there.

## Description of Activity

The curriculum unit is served through WISE (Linn, Clark, & Slotta, 2003), and the simulation activity is designed and run in NetLogo. Students in groups of 2-3 are first asked to decide on a policy outcome (‘commute times’, ‘quality of education’, ‘access to leisure areas’, or ‘pollution’). They are then asked to first explain what they aim to do with this policy outcome (e.g., ‘reduce commute time across the entire population’, or ‘increase quality of education for bottom 20% income bracket’). They are then asked to hypothesize how they will do this, and to articulate some design principles for achieving their social policy outcomes. Once this is done, the NetLogo model is downloaded, and the simulation activity begins.

Students must first re-zone their city and ensure that there is housing and workplaces for all citizens in their city. They can zone five different kinds of areas: Dense Urban Area, Medium Urban Area, Light Suburban Area, Subsidized Housing, and Industrial Zones which contain workplaces. Further, they can designate zones for public parks, and they can build highways and railroads. Once they have finished re-designing their city, they let the city “grow”. This causes new citizens to move to the city. These citizens have an income drawn randomly from a distribution similar to that of the US. Each person finds a job in one of the Industrial Zones, and then decides where to live based on three principles: 1) it must be affordable relative to their income, 2) it

should be close to their spending limit, and 3) it should provide a fast commute to their workplace. In other words: people want to live in a place they can afford, and will then weight the quality of the neighborhood against how convenient it is for their commute. Whenever someone moves into a neighborhood, house prices in that neighborhood and surrounding neighborhoods are adjusted so that the more high-income people move in, the higher the housing prices, and vice versa. This in turn affects who can afford to live there, and thereby affects who move in as more citizens populate the city.

After the city is fully populated, students must investigate how well they did, and reflect on what happened. The model provides two different ways for students to do so: Students can spatially visualize the different outcomes on the map (Figure 1) or they can see bar charts of the distribution of the outcomes per income decile (Figure 2).

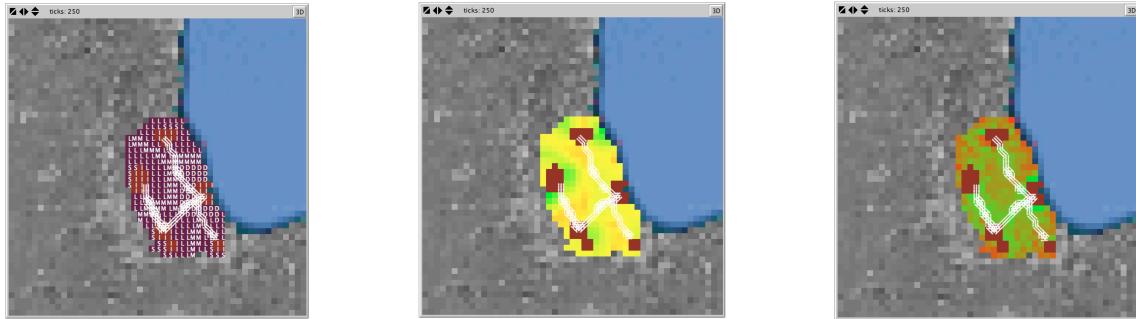


Figure 1: (Left) The designed city, (center) avg. incomes by area, (right) and avg. commute times by area.

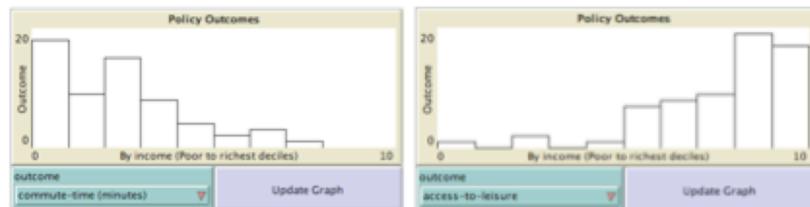


Figure 2: Customizable bar charts per income decile. (Left) Commute time, (right) access to leisure areas.

Students are then encouraged to discuss whether they think they could improve on their designs, and if they choose so, iterate over their designed city until they have re-grown their city in a way they feel meaningfully meets their policy outcome goals, and makes the city a better place to live in. Finally students present their re-grown cities to other groups in the class, accounting for their goals, their outcomes, and their policy and design strategies for achieving them.

## Contributions and Relevance

We believe that agent-based modeling in social sciences education is understudied, and under-designed-for. Agent-based modeling already has a decades long tradition in social sciences research and STEM education, with a focus on mechanism-to-aggregate-outcome explanations of phenomena, and taking a Constructionist approach that enables learners to draw on multiple epistemological resources and connect informal, personal experiences with more formal domain representations. Our curriculum unit draws on this work, but pushes it in a new, exciting direction: Toward social sciences educational contexts.

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# **Colors Of Nature: Connecting Science and Arts Education to Promote STEM-Related Identity Work in Middle School Girls**

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**Abstract:** Art and science share many overlaps in terms of both common practices and habits of mind. In this study, we focus on middle school girls who strongly identify with art and ask the following questions: (1) how does an art-focused approach to science instruction (STEAM) support engagement in scientific practices such as experimentation, observation, and communication of scientific information? and (2) how does a STEAM approach support STEM-related identity shifts in middle school girls?

## **Introduction**

Art and science share many overlaps in terms of common practices and habits of mind. Visual-spatial thinking is key to understanding the structure of molecules, the actions of enzymes, and the 3-D structure of galaxies (Ramadas, 2009). Visual-spatial thinking is heavily used to model abstract scientific concepts (Walker et al, 2011) and is also widely recognized as a central aspect of creating art (Wai et al, 2009). However, much is yet to be learned about how teaching science through art, or connecting art and science teaching, affects science learning. In particular, more empirical work needs to be done on how youth with art-related identities connect to science learning and form science-related identities.

Research suggests that girls who gravitate towards art may have strong visual-spatial abilities that would also serve them well in science careers. However, in contrast to boys, most girls with such ability do not go on to enter STEM careers (Wai, et al, 2009). In formal education settings, little room is often made for explicit instruction on how visual-spatial reasoning and other artistic practices can overlap with science in significant ways. Furthermore, research has found time and again how girls lose interest in science starting in middle school, (Baram-Tsabari & Yarden, 2010). Therefore, the connection between art, science learning and engagement, and identity formation is an important area of research to document empirically. In this study, we focus on middle school girls who strongly identify with art and ask the following questions: (1) how does an art-focused approach to teaching science support (STEAM) engagement in scientific practices such as experimentation, observation, and communication of scientific information? and (2) how does a STEAM approach support STEM-related identity shifts in middle school girls?

## **Methodology**

### **Theoretical Framing**

The building of a science identity, or the sense of oneself becoming a person that does science and is comfortable with science, has been identified by the National Research Council (Bell, et al, 2009) as a central component to successful lifelong science learning and participation. We are particularly interested in the ways in which art-based science learning can lead to shifts in participation in communities of practice. Therefore, we see learning and identity formation as closely interrelated--as youth participate in practices and gain a measure of competence or mastery, those skills may become core parts of a youth's identity at the same time that they get publicly recognized for those skills (Lave & Wenger, 1991). Arts-based science education, in particular that which culminates in public display of some learning product—can lead to such public recognition and identity formation.

However, we also recognize that studying and identifying identity as a construct is empirically difficult as identities are constantly shifting, being formed and re-formed as individuals encounter new practices and resources in communities of practice they engage in (Calabrese Barton et al, 2013). Therefore, in this poster we will focus on and document *shifts* in identity work (Calabrese Barton, et al, 2013), or the ways in which youth engage in science- and art-related practices or the same practices more deeply as a result of a STEAM-based approach to science instruction.

### **Study Context**

The context for this study was a two-week summer academy for middle school girls ( $N = 64$ ) that ran in the summer of 2013. The academy ran for two sessions for two weeks each, once in a large urban city in the Southwestern United States and once in a small city in the far Northwestern United States. The focus of the academy was “the colors of nature”, focusing on the functions of color in biology and art, how color is produced

(optical science and art), and how the practices of science overlap with the practices of artists (observation, experimentation, recording procedures, taking notes, publicly presenting scientific/artistic results).

Researchers assumed the role of participant-observers, sometimes teaching parts of the academy, conducting interviews with participants, videotaping sessions, and taking field notes. Data sources for this study include pre/post interviews, daily videotaped observations of each day of the academy, pre/post STEM and art attitude surveys and content assessments, and analysis of the girls' science and art notebooks that they kept throughout the academy. This project follows a design-based research (DBR) research paradigm (diSessa & Cobb 2004), with cyclical iterations of design, enactment, analysis, and re-design. Therefore, researchers were involved in all aspects of the design process before the academy as well as daily discussions after each day of the academy to talk about learning and refining the design of learning activities.

## Findings and Analysis

Preliminary analysis of data from both summer academies suggest the following findings:

(1) When a STEAM approach to science instruction is taken with girls who are already strongly identified with art, many opportunities open up for connection to emerging identities and everyday practices. For example, art opens up space for mistakes and multiples possibilities in a way that is often challenging for traditional science teaching. Girls, in post-interviews, mentioned that they saw new areas of overlap between science and art, especially in the realm of experimentation, making mistakes, and persisting through science and art projects. One girl said, "Scientists and artists both experiment and make mistakes. The important thing is to keep trying."

(2) We also found that the STEAM approach opened up strong connections to scientific practices emphasized in the Next Generation Science Standards (NRC, 2012), such as observation and experimentation. In post-interviews, girls talked about how having accurate artistic drawings of their observations helps to convey accurate scientific information to other scientists who are not able to observe the same thing as them. They mentioned that both artists and scientists needed to look at problems from multiple perspectives, and that observation through drawing was one way to do that. This also represented a strong connection to everyday practices, as for almost all of these girls, drawing was something that was an important part of their everyday lives and, in fact, helped them think and learn in school. Finally, an unexpected finding was that the STEAM approach to instruction offered another way to look at and appreciate art.

## Significance

Studies have suggested that the formation of STEM-related identities is a significant factor in whether or not youth pursue STEM-related undergraduate degrees (Tai, et al, 2006). This study suggests one way to support STEM-related identity formation in middle school girls by connecting to their already emerging art identities. In this way, this study fits squarely into exploring the conference theme, as we explore who the middle school girls see themselves becoming as they engage in learning science through art-focused practices.

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# **Reel Science: Identity Development through Filmmaking**

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**Abstract:** This study explores how four urban middle school girls co-constructed a science documentary film in an after-school science club. By examining the ways the girls engaged in “core” practices of science and a variety of science, film, and artistic tools and multimodal resources, this study seeks to understand how filmmaking provided unique opportunities for girls to develop positive identities with respect to science.

Researchers have begun to document and explore how youth-produced films provide opportunities for learning and engaging in positive identity development, particularly for youth who often struggle in school settings (Calabrese Barton & Tan, 2010; Halverson, 2010). Increasingly, researchers are attending to the wider range of multimodal resources and practices involved in constructing youth-produced films and the complex ways that identities materialize in and through multimodal texts and create new possibilities for meaning-making (Halverson, 2013; Phal, 2011). This study seeks to understand how four middle school girls participating in an after-school science club co-constructed a science documentary film about bisphenol A (1) (BPA) in their bodies. By examining the multimodal construction of the film *BPA and Our Bodies*, this study explores how film production provided important opportunities for girls to engage in “core” scientific practices and how these opportunities were taken-up or “lived” through multimodal resources. In addition, this study will provide insight into how girls’ identities shape, and are shaped by, participation in culturally relevant science.

## **Research Focus**

The data for this study are taken from a longitudinal ethnographic study of urban middle and high school girls’ identity development in an after-school science club intentionally designed to combat notions of science and “norms” of participation typically perpetuated in school-based science classes. The focus of this research examines the ways that a team of four girls engaged in the construction of a science documentary film over the course of 14 weeks. The core curriculum of the science club focused specifically on scaffolding girls’ authoring of a science story that was informed by engaging in four types of scientific practices: conducting an empirical investigation, critically analyzing published scientific research studies, developing physical models of complex scientific concepts with artistic materials, and interviewing local expert scientists. These four scaffolded science practices were designed to provide opportunities for girls to engage in both practices specific to the culture of science as well as provide a framework on which to build a film. This study explores the ways the team of girls took up and modified these four science practices and engaged with a variety of science, film, and artistic tools and resources in order to represent what they learned about the impact of BPA on the female body. Primary data sources for this study include participant-constructed artifacts, including the final film, participant journals, and visual inquiry investigation maps and filmmaking storyboards. Additional data sources include participant observation fieldnotes and memos, video and audio recordings of girls engaging in the construction of the film, and semi-structured interviews and a focus group with all four participants.

## **Theoretical and Methodological Frameworks**

This study adopts a cultural production theory lens on culture and learning as identity development. Cultural production theory shifts attention to how individuals engage in science in specific contexts with an eye towards the ways that culture is co-constructed and continuously unfolding in the moment (Eisenhart, 2001). Noblit (2013) writes that when culture is conceptualized as a verb, it becomes about actions; it “denotes a sense of becoming” or processes that are not just about sets of beliefs and practices but about the “reproduction and production by people in specific contexts” (p. 244). Cultural production theory provides unique affordances for accounting for the “complex interplay” between individual agency (micro) and societal structures (macro) in the shaping of identities and how these tensions unfold over time (Carlone & Johnson, 2007, p. 1188). Cultural production theory provides a lens through which to examine how girls engage in science in specific contexts while also recognizing the role that broader discourses (i.e. of school, science, gender) play in shaping that engagement.

In addition, this study draws on a social semiotic approach to multimodality that posits that all forms of representation and communication are multimodal and that multimodality implies a theory of learning because learning always entails meaning-making (Kress, 2010; Kress & Van Leeuwen, 2001, 2006). Kress (2010) argues that a social semiotic approach understands identity as connected to the semiotic and conceptual resources that individuals use to engage in communicating within their social and cultural worlds; although these social and cultural worlds are always shifting and changing, multimodality allows us access to understanding how in

particular times and spaces, individuals make meaning by engaging through culturally relevant semiotic resources. “Doing” science and making films requires that individuals to engage in concrete material “stuff” (e.g. chemicals, lab equipment, cameras, editing programs) that are specific to science and film; both rely on visual and embodied modes of communication. The visual and embodied nature of scientific work (observing, representing) through different materials, or modes of communication and representation (i.e. graphs, tables, concept maps) are central to understanding the semiotics of multimodal communication in science (Kress, Jewitt, Ogborn and Tsatsarelis, 2001). As an analytic framework, multimodality provides a lens for understanding the ways that girls engaged with material and conceptual resources in service of authoring a science story through film. As a text, the film provides evidence of how the girls produce their own representations of science, as well as what those representations tell us about the unique identities of those girls. By studying the various semiotic resources (e.g. images, music, printed words, gesture) the girls foregrounded in the production of the film and how the girls took-up the scaffolded science resources and practices (highlighted above) during the construction of the film, this study provides us with a deeper understanding of how this team of girls enacted in a culture of science unique to this materially resource-rich environment.

## Potential significance

Learning science by engaging in core practices specific to the culture of science and constructing visual representations of these practices through artistic mediums for the production of a film requires unique demands of the learner. Analyzing and understanding how the construction of these multimodal representations supports positive identity development provides important insights into how filmmaking provides opportunities to learn science through the media that youth create, particularly for girls who lack opportunities to explore positive understandings of themselves in school science classrooms. In addition, findings from this study deepen our understandings of how historically marginalized girls become participants in science when provided with learning spaces that actively combat traditional notions participation in science.

## Endnotes

- (1) BPA is a chemical produced primarily in the production of polycarbonate plastics and resins and can be found in food and drink packaging. A synthetic hormone that mimics estrogen in the body, BPA has been shown to exhibit hormone-like properties in high doses and has been banned in numerous countries outside of the United States.

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## Acknowledgments

Funding for this research was provided by the National Science Foundation under Grant No. 1114481.

# Identifying and Assessing Computational Thinking Practices

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**Abstract:** Informal programs that allow students to be digital creators appeal to educators who want students to experiment, innovate, and solve problems. To integrate such experiences into formal contexts, educators must name, capture, and assess what students learn from creating in ways that schools value. This poster presents resources to help teachers understand what computational thinking practices look like, how to collect student work that demonstrates those practices, and how to assess that kind of work.

## Major Issue Addressed

Some of the most innovative educational programs are in informal settings—afterschool programs, museums, and youth organizations—where young people are encouraged to explore, discover, and create without the time limitations and curricular and assessment requirements that exist in formal education environments. Freedom to experiment is particularly important for young people learning to create computational media. Scratch is a graphical programming language that has been used in informal settings for a number of years, enabling young people to engage in the process of designing and programming their own projects and sharing them with friends, family, and the online Scratch community. Over the past few years there has been mounting interest in the K-12 education community in helping students develop the habits of mind described as computational thinking (CT), such as systematic problem solving, iterative design, and abstracting from patterns (National Research Council, 2011, 2012). Some teachers and schools have opted to integrate Scratch into their instruction to support the development of CT. However, there are significant challenges to adapting programs originally used in informal contexts to formal schooling on a broader scale (NRC, 2011). One particular obstacle is that it is difficult for school districts to commit to integrating content that they cannot readily assess (Grover & Pea, 2013), and currently there are no comprehensive assessments of CT applicable for a wide range of K-12 educational contexts. This poster is intended to initiate a conversation about CT assessment, by presenting a suite of resources created to help teachers understand a) what computational thinking practices look like when students use a particular programming language (Scratch), b) how to collect examples of students engaging in computational thinking practices, and c) how to assess those examples of student work.

## Potential Significance of the Work

Understanding how CT and, more broadly, design thinking align with teachers' and administrators' larger educational goals, and helping them recognize the value of this kind of thinking is critical for innovative, informal computer programming and digital design programs to take hold in formal educational settings.

## The Theoretical and Methodological Approaches Pursued

Policy makers and education leaders have recognized the need for young people to have a greater understanding of how computers and other technologies work, how they are designed, and the logical processes upon which computing is based (Guzdial, 2008; Wing, 2006). The CT education research community faces challenges as it advocates for integrating CT into the K-12 curriculum. First, defining a framework for CT remains an ongoing topic of debate (NRC, 2011, 2012). Second, clarifying for the larger education community how knowledge gained from programming and design experiences can transfer to other domains remains a challenge (Han Koh, Basawapatna, Bennett, & Repenning, 2010). Third, developing strategies for assessing CT is critical for adoption in formal school settings, but currently lacks coherence (Brennan, & Resnick, 2012).

The authors were involved in a program to help teachers integrate Scratch into formal instruction. The program developers created professional development opportunities, curricula, and resources for educators. The program researchers were tasked with developing a method for assessing students' development of computational thinking as they used Scratch. This first required a definition of computational thinking by the program developers. Initially, their definition was based on both definitions being formulated in the CT education community and their own experiences seeing young people engage with Scratch in informal settings. The initial CT framework included what they called "computational concepts, practices, and perspectives." Concepts included items such as loops, conditionals, parallelism, etc.; practices included iterating, debugging, abstracting, and reusing; and perspectives included expressing, connecting and questioning.

Using this framework the researchers created protocols for conducting interviews of students talking about their projects and debugging problems in the code. We recorded these using screen capture technology,

which records audio and actions on the computer screen. We interviewed 36 students at the beginning, middle, and end of the units in which they learned Scratch (a total of 91 interviews). We also conducted interviews with twelve teachers at the beginning, middle, and end of their units about their experience integrating Scratch into their instruction, how they were assessing students' Scratch work, and what kinds of assessments and resources they needed to help themselves and their colleagues understand what students were learning with Scratch.

## Preliminary Findings

Our analyses of student screen captures and teacher interviews indicated that the most important area to focus on was the CT practices, rather than the concepts or perspectives. Teachers either already were capable of assessing the concepts (if they were computer science teachers) or the concepts were not the main goals of instruction (if they were subject area teachers). Computational perspectives were too varied to operationalize and capture reliably. The CT practices, however, could be operationalized, were relevant for a wide range of teachers, and yet were not generally being assessed because they were about process rather than product. The researchers and developers revised the CT practices framework and developed a range of resources for teachers to use in their instruction, which we piloted with two elementary school teachers, two middle school teachers and one high school teacher. We found through the pilot studies that teachers were able to adapt the assessment materials to a range of teaching situations (high school computer science, middle school technology class, elementary school science), and that students at different age levels were able to complete the assessment materials. The pilot feedback led us to finalize the CT practice framework:

- *Experimenting and Iterating*: Developing a little bit, then trying it out, then developing some more  
This is characterized by the following practices: a) Build a project step by step, b) Try things out as you go, c) Make revisions based on what happens, d) Try different ways to do things, or try new things.
- *Testing and Debugging*: Making sure things work –finding and solving problems when they arise  
This is characterized by the following practices: a) Observe what happens when you run your project, b) Describe what is different from what you want, c) Read through the scripts to investigate the cause of the problem, d) Make changes and test to see what happens, e) Consider other ways to solve the problem.
- *Reusing and Remixing*: Making something by building on existing projects or ideas  
This is characterized by the following practices: a) Find ideas and inspiration by trying other projects and reading the scripts, b) Select an image, sound or script and adapt it for your project, c) Modify an existing project to improve or enhance it, d) Give credit to people whose work you build on or are inspired by.
- *Abstracting and Modularizing*: Exploring connections between the whole and the parts  
This is characterized by the following practices: a) Decide what sprites are needed for your project, and where they should go, b) Decide what scripts are needed for your project, and what they should do, c) Organize the scripts in ways that make sense to you and others.

The teacher resources we developed included: a) Video exemplars of elementary, middle and high school students engaged in each of the practices, b) A teacher self-reflection tool for assessing whether lessons provide opportunities to engage in the practices, c) A set of student reflection questions asking students to show how they engaged in the practices, d) Examples of methods for collecting students' reflections on their practices, e) Examples of students' responses to reflections and sample assessments of the quality of their work.

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# **Undergraduate Attitudes Towards Help-Seeking**

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## **Introduction**

Appropriate help-seeking is a necessary skill in becoming a successful self-regulated learner (Newman, 1994), however many students under-use or abuse the help facilities offered to them by interactive learning environments (ILEs) (Koedinger & Aleven, 2007). A variety of dispositional factors affect student help-seeking practices and social concerns are often under-explored in the context of individual ILEs. In our work, we focus on undergraduate students, because they may still struggle with social factors in their desire to build and maintain a positive social identity in the new and sometimes intimidating university context. This paper presents results from a survey study that provides foundational insights into the factors affecting student help-seeking practices in our target student population.

Nelson-Le Gall (1981) proposes a model of help-seeking in classroom contexts in which the student must (1) first become aware of a help need, (2) decide to seek help from an external source, (3) identify potential helpers, (4) implement strategies for engaging the helper, and (5) reflect upon the help-seeking attempt. Aleven et al (2003) adapt this model to ILEs, stopping short of examining the help-seeking process in collaborative ILEs. Of particular interest to our future work is step 2 (students' decisions to seek help) and step 4 (strategies for seeking help). We propose that student dispositions should impact whether and how students seek help, and explore this hypothesis in this survey.

Our future work examines how manipulating public threats to self-esteem might interact with student dispositions and private threats to self-esteem to affect their help-seeking. We will manipulate evaluation apprehension and public threats through a variety of means: social role of the tutor, social/technical presence of the tutor, relationship between the collaborators, and public/private help facilities. But first, we must understand if our potential students encounter difficulties seeking help, and if there are particular student dispositions or social situations that lend to more help-seeking.

## **Method**

Participants include 26 participants (14 female, 12 male) with a mean age of 19.7 years ( $SD = 1.49$ ) from a university in a small city, who completed a self-report questionnaire. In our questionnaire, the variables of interest include (1) student dispositions and (2) help-seeking strategies. Previous literature suggests that dispositions, including shyness, personality, gender, self-esteem, and achievement goals might impact help-seeking. Our self-report questionnaire uses a Shyness scale (Cheek, 1983), the short version of the Big Five Personality Index (Rammstedt & John, 2007) (openness, conscientiousness, extraversion, acceptance, and neuroticism), the one item self-esteem scale (Robins et al, 2001), and Midgley et al's (2000) PALS achievement goal questionnaire (mastery-oriented, performance avoidance-oriented, and performance approach-oriented).

Our help-seeking strategies outcome items come from Wolters et al (2003) and consist of measures for general intention to seek needed help, general intention to avoid needed help, perceived costs of help-seeking, perceived benefits of help-seeking, instrumental (autonomous) help-seeking goals, expedient (executive) help-seeking goals, seeking help from formal sources (e.g., teachers), seeking help from informal sources (e.g., peers), as well as perceived teacher support of questioning.

## **Results and Conclusions**

As this is a questionnaire study, relationships between factors are correlational. One would generally predict higher self-esteem, mastery-orientation, and extraversion to be correlated with higher self-reports of positive help-seeking and to see dispositions such as performance-approach to be related to more negative outcomes such as expedient help-seeking. Basic statistical information on our items is included in Table 1, and we discuss correlations of interest below.

Personality indicators of openness as well as performance-approach achievement goals were not significantly related to any help-seeking attitudes. Also, attitudes toward seeking help from formal sources do not appear to be related to any measured dispositional attributes. We see that perceived costs and benefits of help are rather similar, with the costs being slightly more apparent to students than benefits. Surprisingly, seeking help from informal sources was reported with low scores, but when we look at the correlational results in Table 2, we see that students low in self-efficacy reported a greater preference for seeking help from peers, as well as students reporting low amounts of mastery-oriented goals and higher amounts of performance-avoidance.

**Table 1: Basic statistics on our help-seeking survey items.**

<b>Item</b>	<b>Example</b>	<b>M</b>	<b>SD</b>
<i>Intention to Seek Help</i>	If I needed help in this class I would ask someone for assistance	4.96	0.90
<i>Intention to Avoid Help</i>	If I didn't understand something in this class, I would guess rather than ask someone for assistance	3.23	0.93
<i>Perceived Costs of Help</i>	Getting help in this class would be an admission that I am just not smart enough to do the work on my own	4.22	0.92
<i>Perceived Benefits of Help</i>	Getting help in this class would make me a better student	3.95	1.20
<i>Instrumental Help-Seeking</i>	I would get help in this class to learn to solve problems...by myself	4.44	0.53
<i>Executive Help-Seeking</i>	The purpose of asking somebody for help in this class would be to succeed without having to work as hard	4.49	0.68
<i>Help from Formal Sources</i>	If I were to seek help in this class it would be from the teacher	4.71	1.25
<i>Help from Informal Sources</i>	If I were to seek help in this class, it would be from another student	2.60	1.16
<i>Teacher Support of Question</i>	The instructor tells students to interrupt her whenever they have a question	4.3	0.70

Our initial results show a spread of opinions about help-seeking. This suggests that some students do have obstacles when seeking help, so interventions to reduce social apprehension may help reduce help-avoidance. Furthermore, we see some expected connections between our measures of student dispositions and help-seeking outcomes, especially self-esteem, extraversion, and mastery-orientation. Results showing that mastery learning-oriented goals are negatively correlated with seeking help from informal sources are interesting because that suggests that learning-oriented students prefer not to ask for help from their peers. One possible explanation for this is that perhaps these students do not think their peers can help them sufficiently. Overall, we see support for varying opinions about help-seeking, and mostly correlations between greater confidence and positive help-seeking beliefs. This suggests that it may be more difficult to find relationships between less beneficial dispositions and help-seeking beliefs which may add complexity to future interventions.

**Table 2: Correlations between help-seeking attitudes (rows) and dispositions (columns).**

	<b>Self esteem</b>	<b>Self-efficacy</b>	<b>Shyness</b>	<b>BFI-Cons</b>	<b>BFI-Extra</b>	<b>BFI-Accept</b>	<b>BFI-Neur</b>	<b>Mastery</b>	<b>Perf-Av</b>
<i>Seek Help</i>	.48**		-.34*		0.48**		-.56**		-.41**
<i>Avoid Help</i>	-.47**	.35*		-.34*		-.44**		-.52**	
<i>Costs</i>	.57**				.55**		-.44**		-.41**
<i>Benefits</i>	.63**	-.53**			.61**	.43**	-.60**		
<i>Instrumental</i>			.37*					.47**	
<i>Executive</i>	.45**								
<i>Formal Src</i>									
<i>Informal Src</i>		-.41**						-.64**	.44**
<i>Teacher Sprt</i>	.50**				.41**				

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# Becoming a Professional through Virtual Practice

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**Abstract:** Disciplinary practices are challenging to teach and assess, yet are integral to persistence and future success. This poster presents findings from an online, interactive case study system that allows learners to take on expert roles—in this case, dietitian—and learn content as they counsel virtual patients. We present results from two design-based research implementations, and preliminary findings from an ongoing third implementation. Analysis reveals that undergraduate and graduate nutrition students learned about professional practices.

## Major Issues Addressed

A major challenge for educating professionals is providing experiences that help them connect content to professional practices. For instance, nutrition assessment is a core professional practice, yet is difficult to teach. Myriad strategies have been sought for improving student learning in nutrition/dietetics courses, including experiential approaches and interactive online approaches. Increasingly, there has been a push to move instruction online. A systematic review assessed postsecondary online nutrition education courses, showing that online instruction was comparable to face-to-face nutrition courses in terms of learning gains, but less success has been found for changing perceptions (Cohen, Carbone, & Beffa-Negrini, 2011). Understanding more about the design of such environments is key to abstracting how or why they might support learning or foster change in perceptions. In research conducted with focus groups, students reported various challenges; of particular relevance to the current study is one challenge in particular: way-finding. Organizing relevant resources in an intuitive manner can support students to make productive and repeated use of them (Connors, 2012). Interactive, online instruction significantly increased paraprofessional knowledge, but at a greatly reduced cost (as compared to face-to-face training) (Christofferson, Christensen, LeBlanc, & Bunch, 2012).

## Significance

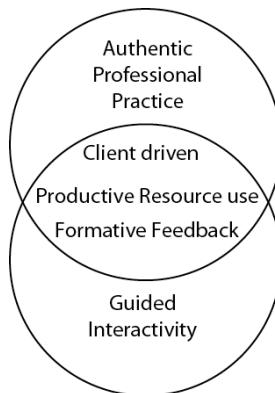
The current study reports a combined experiential, interactive online approach that provides authentic context, which has been shown to support learning (Rivet & Krajcik, 2008). Our system (system name blinded for review) allows students to try on professional roles (e.g., dietitian), use resources (e.g. journal articles) and apply conceptual understanding by counseling virtual clients (e.g., a patient with diabetes). Our system helps students see connections to their future professional selves. Past research on our system focused on high school life science, placing students in roles such as genetic counselor or conservation geneticist and asked to counsel virtual clients using resources, including the internet, to prepare responses. Our system helped identify misconceptions students held, which could be addressed adaptively, because our cases are formative (Black & Wiliam, 1998); this approach enhances participation (Hickey, Barab, Ingram-Goble, & Zuiker, 2008) and increases retention for students with low confidence about accurate ideas (Butler, Karpicke, & Roediger, 2008). Our system provides a safe atmosphere for students learn how to interact with patients around a new subject area. Other strategies that would provide a similar experience such as standardized patients can be cost prohibitive, particularly for undergraduate education.

## Theoretical and Methodological Approach

Our research uses Design-Based Research (DBR) (The Design-Based Research Collective, 2003). The purpose of DBR is to iteratively develop theories of and designs for learning (The Design-Based Research Collective, 2003). This paper reports two initial iterations (with a third in progress at time of writing) of a longer DBR study. Theory is instantiated in our designs for learning, and iteratively tested under real-world conditions to better understand how, when, and for whom learning occurred. The beginning theoretical stance is depicted in Figure 1.

## Participants and Setting

Students in DBR Iteration 1 ( $n=15$ ) and 3 ( $n=30$ ) were recruited from an undergraduate course on nutrition through the life cycle. Students in DBR Iteration 2 were recruited from a graduate course ( $n=14$ ) on nutrition assessment. All courses were taught by one of the authors who is a faculty member in a nutrition program at a research university in the southwestern US. The case was completed as a course assignment. Students in iterations 1 and 2 completed one out-of-class case in 2-3 hours. Students in the ongoing iteration 3 are completing 8 cases distributed throughout the course.



**Figure 1.** Beginning theoretical stance for supporting learning

## Findings, Conclusions and Implications

Students overwhelmingly reported that they would use what they learned in other classes and in their careers, and that what they learned was important for their future professional work. Students also agreed that the case resembled a real life situation. Students who chose incorrect answers on the interactive case still performed well on the delayed post test. On the delayed post test, the average score was 98% for items related to the interactive case. In contrast, the average score for items targeting traditional (paper-based) cases was 89%. While not a large difference, this suggests that students may retain what they learn in these cases better than traditional approaches.

## Connection to Conference Theme: Learning and Becoming in Practice

The purpose of the study was to develop and pilot test interactive cases to help nutrition students (1) understand aspects of a professional practice, the Nutrition Care Process (Assessment, Diagnosis, Intervention, Monitoring & Evaluation), and (2) learn to make relevant professional decisions. We found that the cases supported both undergraduate and graduate students to do this. Our study extended our prior framework from high school students to undergraduate students at the very beginning of understanding professional practices and graduate students looking to extend their professional practice. Our research provides an exemplar of an efficient and feasible experiential approach to providing students a vision of practice.

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## Acknowledgments

The authors would like to acknowledge funding from a UNM Teaching Allocation Grant (#734059) and from the USDA/NIFA Hispanic-Serving Institutions (HSI) Education Grants Program (#2012-38422-19836).

# **Community-Based Engineering and Novice Elementary Teachers' Knowledge of Engineering Practices**

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**Abstract:** The goal of our research is to study the extent to which a community-based engineering component of a teacher education program can impact new elementary teachers' abilities to identify and respond to students' science and engineering ideas and practices. Our mixed methods study design includes a novel Video Case Diagnosis task where teachers analyze video of elementary students discussing engineering design problems.

## **Introduction**

According to the writers of the *Next Generation Science Standards* (National Research Council, 2013), one fundamental way in which the *NGSS* differ from previous national science education frameworks is that engineering design has been elevated "to the same level as scientific inquiry in science classroom instruction at all levels" (NRC, 2013, p. 337). This shift raises new questions for the elementary teacher education community. How can teacher preparation programs help pre-service teachers develop the knowledge and understanding they need to include both science and engineering practices in their elementary classrooms? Previous work reveals strategies for improving novice teachers' competence in inquiry-based science teaching (e.g., Forbes, 2011). However, there is limited research on how elementary teachers learn to teach engineering design (Hsu, Cardella, & Purzer, 2010), and preparing pre-service teachers to guide their students in both engineering design and scientific inquiry is a new challenge.

In response to this challenge, we propose to develop and investigate an innovative model that introduces novice elementary teachers to "community-based engineering design" as a strategy for teaching and learning in urban schools. The goal of our research is to explore how community-based engineering experiences can contribute to new elementary teachers' abilities to identify and respond to students' emerging science and engineering ideas and practices. The study is in its early stages. In this poster we report on our initial yet significant effort to understand novice teachers' understandings of science and engineering practices with an instrument we introduce as the Video Case Diagnosis task.

## **Theoretical Approach**

Our work is framed by engineering design cognition literature (e.g., Cross, 2004), situated learning theory (e.g., Lave & Wenger, 1991), and the resources perspective on children's science learning. Focused on the "productive conceptual, meta-representational, linguistic, experiential, and epistemological resources that students have for advancing their understanding of scientific ideas" (Warren et al., 2001, p. 531), the resources perspective is aligned with the idea that students come to school with "funds of knowledge" from their experiences at home and in their communities (Moll, Amanti, Neff, & Gonzalez, 1992). These funds of knowledge can be used as a foundation for engaging students who are typically left on the margins of school science. A key objective of the proposed study is to use community-based engineering experiences as a situated learning context to help new teachers identify and build upon the resources of students in urban elementary schools. Studies of professional engineers have revealed that the enterprise of engineering draws upon individuals' cognitive, sociocultural, and affective resources (Cardella, Atman, Turns, & Adams, 2008).

Our research question has two parts: During the course of community-based engineering experiences, what is the evolution of novice urban elementary teachers' (a) understandings of engineering practices and their relationship to science practices and (b) identification and response to *students'* engineering and science ideas and practices?

## **Methodological Approach**

Participants in the study are graduate students in their final year of an elementary teacher preparation program. During their science teaching methods course, they solve a sample community-based engineering problem developed by the course instructor and expert elementary science educators and design and implement a community-based engineering mini-lesson. A subset of participants then attends a summer institute where they create and implement with elementary students a full community-based engineering module that is connected to the school district's science curriculum.

We employ a mixed methods study design. We measure teachers' understandings of science and engineering practices with a new instrument called the Video Case Diagnosis task. Building upon work that uses video cases of student work in science and mathematics (Hammer & van Zee, 2006; Norton, McCloskey, &

Hudson, 2011; van Es & Sherin, 2008) the VCD task asks novice teachers to watch a brief video of elementary students attempting to solve an engineering design problem. It then asks teachers to list (a) the ideas that the students express about science phenomena and engineering solutions, (b) the science and engineering practices in which the students engage, and (c) three suggestions for how the teacher could respond productively to the students. To develop the scoring rubric, we synthesize expert science educators' and science education researchers' responses to create an "exemplar" answer for each video case (Norton et al., 2011). Additional data sources for the overall study include video recording of the novice teachers during community-based engineering tasks and written artifacts from the summer institute and methods course assignments, which involve the critique and revision of science and engineering lessons.

## Preliminary Findings

Our preliminary findings are primarily based on the initial administration of the Video Case Diagnosis task. This exploratory stage serves the dual purpose of informing us of novice teachers' initial understanding of science and engineering practice and serving as a pilot version of the instrument. Thirty elementary pre-service teachers participated in this pilot run. The video featured two fourth-grade students engaged in conceptual planning for a device that could lift a heavy object out of the ocean. The boys use verbal language, written notes, sketches, and rough physical prototypes to communicate their design ideas to each other and create an initial design plan. Preliminary analysis of teacher responses indicates that they tend to focus on two aspects of the students' work: a) students' use of science and engineering technical vocabulary (e.g., "lever," "weight") and b) the students' physical prototypes, including the rudimentary lever the students created out of a water bottle and pencil. Preliminary analysis also indicates that the teachers do not frequently notice the important engineering practices of problem identification and consideration of multiple solutions. In our poster we present detailed findings from these initial exploratory stages.

## Relevance to Conference Theme: "Learning and Becoming in Practice"

Our work contributes to the conference theme through its dual focus on pre-service teacher engagement in engineering practice as well as their learning to notice and respond to young students' science and engineering practice. We investigate how novice teachers, especially in tightly constrained urban elementary schools, *learn* about science and engineering practice, and *become* science and engineering educators.

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## Acknowledgments

This work was supported by the National Science Foundation under Grant 1253344. Any opinions, findings and conclusions expressed here are those of the authors and do not necessarily reflect the views of the NSF.

# **Using Classroom-Based Authentic Research Experiences to Foster Scientific Thinking and Representational Competence**

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**Abstract:** In this preliminary mixed-method investigation, we explore how course-based research experiences using virtual supplements facilitate students' thinking and communicating like scientists. Our initial findings, from one institution ( $n=54$  students), indicate that this experience has improved students' communication, representational competence, understanding about scientific processes, and professional identities. We anticipate that these findings will be consistent across all five institutions we are targeting.

## **Issue Addressed**

One of the best ways for students to understand how scientific knowledge is generated is through participating in the authentic practice of science through research. However, opportunities for research experiences are often limited and competitive. There is a need to provide more undergraduates with authentic interdisciplinary research experiences (AIRE) and assess their impact (AAAS, 2010). One way to provide research opportunities to more students is to integrate AIRE into the classroom. Ideally, classroom-based AIRE help students learn the process of science as they are guided to act and think like scientists while contributing to scientific discovery. Communication is an important aspect of science and advancements in technology have changed the way scientists communicated. Biological databases have grown significantly with the advent of genome sequencing technologies and the explosion of the internet has provided multiple options for sharing data and meeting virtually. Technology is integrated at multiple points during the process of scientific discovery as collection, analysis, and dissemination of data often relies on multiple virtual environments (VE) on the computer. Thus, AIRE for students should include the integration of technology. Technology (e.g., blogs, virtual worlds, and wiki spaces) can help create professional research communities and link students across institutions that are all participating in AIRE. Students can use this technology to communicate about problems, conceptual understandings, trouble shooting, and interesting findings (Clase and Halverson, 2013; Johnson et al., 2002; Kangassalo, 1994). The purpose of this investigation is to explore how course-based AIRE integrated with VE facilitate students' thinking and communicating like scientists.

## **Theoretical Framework**

We used the Representational Competence framework (Halverson and Friedrichsen, 2013) to guide this study and we are testing its application for exploring changes in student thinking about annotated genomes and its relation to a biological system. Representational competence is the varying ability of an individual to understand and use representations when explaining complex phenomenon (e.g., a biological system). The seven levels identified range from no use to expert use of representations. Level 1: No use of representation; students are unable to create a representation. Level 2: Superficial use of representation; students create literal images to illustrate a scientific concept (e.g., drawing a scientist extracting DNA). Level 3: Simplified use of representation; students create representations with components of the concept, but these are not complete (e.g., drawing chromosomes only without annotation). Level 4: Symbolic use of representation; students' representations are based on a conceptual understanding of the phenomena; however their understanding is flawed. Level 5: Conceptual use of representation; students' are unable apply the information in their representations to their accurate conceptual understanding. Level 6: Scientific use of representation; students create accurate representations and descriptions, but demonstrate limitations justifying which representation is most appropriate within a given context. Level 7: Expert use of representations; students are able to generate multiple representations and use them to accurately explain a complex phenomenon.

## **Methodology**

Our study explored the following research questions: 1) How can an AIRE influence students' levels of representational competence? 2) In what ways do students use representations to communicate their ideas like expert scientists? 2a) How does student thinking change after participating in an AIRE? 2b) How do students use representations to think about components within a biological system and across scales? 3) How do students react to using VE as part of AIRE classroom instruction? We are currently in the process of collecting and analyzing data for this mixed method investigation. Participants include students enrolled in AIRE introductory biology courses across five research universities in the US, about 15-40 students (all 18 years old or older) per course (or course series). Data comes from student responses on pre/post assessments measuring biological content knowledge, attitude about science, and representational competence for genomes, individual semi-

structured interviews with students after participating in course-based AIRE, and reflection prompts collected throughout the semester. Data for our preliminary findings come from one of the universities (n=54). We analyzed data using qualitative and quantitative methods. For the qualitative portion, we first used a deductive coding method to analyze student responses on the pre/posttest and individual interviews by grouping students' drawings and explanations into the levels of representational competence (Author, 2013). Then, we used an inductive approach to code students' responses from individual interviews to identify themes of students' reactions to using VE. These themes included scale perception, logistical aspects, communication, content visualization, and perceived purposes for integrating VE into AIRE. For the quantitative portion, we analyzed responses on pre/posttest using a Repeated Measures ANOVA to identify changes in attitudes toward science.

## Preliminary Findings

According to our findings from the first university that offered a two semester course-based AIRE, students' showed gains in communicating like scientists and representational competence. Before instruction students demonstrated limited use of representations to communicate understandings, and much of this content was inaccurate. After instruction more students were able to conceptually understand and use representations in their explanation of an annotated genome. Overall, only 5% of participants achieved the highest level of representational competence. Even though not all students were skilled at using representations to communicate their scientific understandings, all students involved in the course were able to verbally describe what they were doing for their research project. They discussed how the act of doing science helped them better understand that scientists have to make choices about what they are finding. Furthermore, the students used the evidence they collected to make decisions, such as what constituted a gene, and also acknowledged that although their defined gene may not be right, it's their best guess based on the data they had examined thus far. The student drawings of an annotated genome resembled the genome visualizations from the VE used in the course. Although most students discussed a single computer image that influenced their representation, students who demonstrated the highest level of representational competence made comparisons among the multiple computer images. In addition, only students that completed the entire AIRE (both semesters) demonstrated an awareness of the genome from a biological systems perspective, making connections to proteins and biological function across organisms. We also found that VE helped facilitate a professional identity among the students. They reported the VE as helpful for recognizing the scale of their AIRE at a national level, beyond the work completed in the course. They reported value in being able to use a VE to "see" the concepts they had been investigating in the lab, such as a genome and they found VE useful for communicating their project to students at other institutions working toward similar goals. Students also engaged in using VE to help with problem solving when they experienced experimental difficulties.

## Conclusions and Implications

While our current findings are only preliminary, they provide evidence that it is possible to offer AIRE in a classroom-based setting and allow more students the opportunity to have these experiences meeting the need identified by AAAS (2010). In these AIRE cases, students are afforded opportunities to develop insights into how scientific knowledge is really developed and provided with authentic ways to communicate understandings with others, particularly if paired up with VE supplements. This idea of communicating and collaborating with others was a key aspect to helping students feel like contributing scientists. We anticipate that the findings from this one university will be consistent with the other four institutions we have partnered with for this project.

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## Acknowledgments

This collaborative research was supported by funds from a GRC Visionary Grant, the NIH, and HHMI.

# Scaffolding Argumentation Competence: The Shift from First to Second Order Skill Acquisition

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**Abstract:** This conceptual article argues that the focus of research on argument-scaffolds should shift from first-order towards second-order scaffolding. If learners acquire argumentation skills and learn to self-direct argumentation activities, they also engage in epistemic discussions with partners that help them acquire knowledge, correct false viewpoints and refine misunderstanding. This article presents a 3-step guideline for second-order argument-scaffolding, namely (1) diagnosis of internal argumentative script, (2) adaptive external support, and (3) adaptive fading of external support.

## Introduction

Argumentation is an essential aspect of scientific thinking and entails the ability to reason by applying rules of formal logic to deal with complex problems in academic settings. Research on fostering educational argumentation as a pedagogical approach for collaborative learning has been influenced by developments in technology-enhanced environments focusing on the role of computer-support systems for scaffolding various aspects of argumentation processes (see Noroozi et al., 2011, 2012, 2013a, 2013b, 2013c). Various instructional scaffolds have been embedded in online environments through graphical representational tools in the form of schemes, tables, or visualizations to support dialogical argumentation processes, or in a more textual implementation in the form of cues, prompts, or scripts to orchestrate various roles and activities of learners for procedural scaffolding of specific interaction patterns (see Kirschner et al., 2003; Scheuer et al., 2010; Noroozi et al., 2012 for an overview). The scaffolds developed, implemented and researched up until now have been meant primarily to stimulate argumentative discourse activities for learning within a particular domain (i.e., to achieve effects with argument scaffolding) and not to help learners acquire argumentation skills and self-regulate them for application in new situations (i.e., to achieve effects of argument scaffolding). The focus of argument-scaffolds should not only be on providing support for the performance of the complex skill (first-order scaffolding) but also on decreasing that support over time for promoting acquisition of self-directed learning skills (second-order scaffolding) (see Merriënboer & Kirschner, 2013).

The process of acquiring argumentation skills can differ depending on the learners' own individual, already developed, and often idiosyncratic internal script that indicates how a person will act in and understand a particular situation (see Kollar et al., 2007). An argumentation script can be seen as a specific instantiation of a CSCL script. "A [CSCL] script describes the way students have to collaborate: task distribution or roles, turn taking rules, work phases, deliverables, etc. This contract may be conveyed through initial instructions or encompassed in the learning environment" (Dillenbourg & Jermann, 2007, p. 275). In turn, an internal argumentation script is an instantiation of what Fischer et al. (2013) call an internal collaboration script: "a configuration of knowledge components [that a person has] about a collaborative practice and its parts at different levels of complexity...that guide the person's understanding of and actions in the collaboration" (p. 57) while an external script is "a configuration of representations (e. g. textual or graphical) of a collaborative practice and its parts at (potentially) different levels of complexity...presented to a group of learners by an external source (e.g., a teacher or a website interface) as a means to guide their collaborative activities" (p. 57).

Scientific evidence suggests that the optimal learning scenario - in this case acquiring and applying argumentation skills - depends on the interplay between external and internal scripts (see Kollar et al., 2007), meaning that overly detailed instruction impedes learning when the provision of the external support inhibits the learner's self-regulated application of the internal script (Fischer et al., 2013). In such a situation, the external script may interfere with the internal script. Specifically, this occurs when the external script targets already developed internal script components that do not need further scaffolding or targets them in a way that conflicts with how the person already effectively works rather than targeting those internal script components that need to be scaffolded. As a result, processing these unneeded or interferential/conflicting scaffolds not only may cause unnecessary cognitive load but may also prevent developing higher level internal script components by taking away the self-regulation from the learners (see Fischer et al., 2013).

External scripts will only be effective when they trigger the accompanying specific collection of internal script components, if these internal script components exist in the learner or if the external scripts do not conflict with or are not redundant to the internal script components. In this situation, learners are first supported by the external scripts to further develop their corresponding internal script components by repeated application

and are then given the opportunity to practice and apply their newly developed internal script components for regulating their activities, which in turn results in the internalization of the external scripts and enrichment of the internal script (Fischer et al., 2013). This situation is particularly effective for learners when their idiosyncratic internal script is or becomes similar to the external script. Internalization of the external script and development of the internal script occurs if and when the learner is aware of the corresponding activities and the underlying reasoning behind the activities; otherwise it becomes a procedure aiding the student at that moment (i.e., effects with) that will not be transferred to other relevant situations (i.e., effects of). Fading external scripts or gradually transferring the learning responsibility from the environment to the learner has been argued to be an effective approaches to realizing an optimal interplay between external and internal scripts (see Kollar et al., 2007). However, additional support during the fading is needed if learners are to dynamically reconfigure their internal script components as a response to changing situations and their individual goals to continue acting in accordance with the strategy suggested by the external script (Fischer et al., 2013; Wecker & Fischer, 2011).

Few instructional approaches have been proposed to complement fading for internalizing and securing continuous application of the strategy in external scripts. This conceptual paper uses a narrative analysis approach to synthesize and integrate literature on this topic with the goal of developing a guideline for second-order scaffolding of collaborative argumentation-based learning and for addressing practical implications and avenues for future research. This paper proposes a 3 step guideline for scaffolding collaborative argumentation-based learning in such a way as to secure acquisition and continuous application of the argumentation strategies, namely 1) diagnosis of the internal argumentative script, 2) adaptive external support, and 3) adaptive fading of this external support. Specifically, this paper suggests mechanisms in which automated analysis techniques can be used to recognize the internal scripts of both individuals and groups of learners and their learning processes for providing dynamic support and adaptive fading. It also suggests to combine artificial intelligence and computer-linguistic tools to provide learners with dynamic support and adaptive fading depending on their argumentative discourse activities. Finally, this paper suggests to complement adaptive fading support with self-assessment, peer-assessment, and automatic response tools to ensure that learners actually understand and learn the targeted argumentative activities in the external support.

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# Multiple-Text Processing in Text-Based Scientific Inquiry

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**Abstract:** This study examined multiple-text processing in the context of text-based scientific inquiry for purposes of generating causal models. We used a series of rubrics to examine students' use of the texts, the quality of the causal models they created, and the impact of text use on model quality. Results indicate that multiple text users engaged with the texts in qualitatively different ways and created significantly higher quality models than single text users.

## Objectives

This study examined how students used an intentionally designed text set to generate causal models of the carbon cycle prior to and following an instructional intervention. Using a series of rubrics, we analyzed the pre/post models to determine the extent to which students made use of the texts and the quality of the models that they created. We then examined the relationship between text use and model quality, focusing on the role of multiple-text processes.

## Theoretical Framework

Consistent with authentic practices of the discipline, scientific literacy involves working with multiple sources to acquire information (Chinn & Malhotra, 2002). When scientists read articles to advance their understanding of a phenomenon, they engage in multiple-text processing to evaluate, corroborate, and synthesize sources of evidence for particular models and theories (Bazerman, 1985). However, novices tend to approach sources separately and uncritically, failing to notice connections among them (Wolfe & Goldman, 2005). Text processing research provides insights into the challenges associated with multiple-text processing and the role of this practice in scientific understanding. Initial research indicates that deep engagement in text processing plays a role in understanding, but additional work is needed to examine this relationship. The current study endeavors to build on this body of work by examining the ways that students make use of multiple texts in a text-based inquiry context and the impact of text use on scientific understanding as represented by model quality.

## Methods and Data Sources

This study occurred in the context of an ongoing design-based research project investigating evidence-based argumentation and multiple text use in middle and high school history, science, and literature classrooms (Goldman et al., 2009; Greenleaf et al., 2013). The specific focus of this study is a three-week implementation of a text-based inquiry module on the water cycle conducted in a 6th grade science classroom located in an urban, Midwest public school. Pre and post module, students completed an assessment that engaged them in the same reading and inquiry practices taught during the module but for a different topic. The pre/post text set was designed to facilitate an investigation of students' text use and multiple-text processing in that it required the selective use of information from multiple texts and cross-text synthesis to produce a complete causal model. The four texts included several different types of information, including running text and illustrations. During the pre/post assessment, students were asked to read and annotate the texts. They were then asked to use information from the texts to create a model that explained how and why the scientific phenomenon occurred. The pre/post assessment was administered individually to each student in the class one day prior to and two days following the instructional module. Pre- and post-test data were available for 22 consented students.

The analytic approach was designed to capture the range of performances on the pre/post modeling task across students and changes in performance from pre to post instructional intervention. The performances of interest were students' use of the texts and the causal models that they constructed. The pre/post assessment was administered individually to each student in the class one day prior to and two days following the conclusion of the instructional module. Pre/post test data was available for 22 consented students.

The models constructed during the pre and post assessment constitute the data source for this poster. These models were coded for text use and model quality using two rubrics that were developed through an iterative refinement process of generating criteria, applying them to student work, and revising the criteria to effectively capture variation.

Rubric for text use. This rubric allowed us to trace the information in each model to the texts that each student used to create their model. We identified the type of information that was used including 1) running text, 2) illustration. Overall text use was evaluated based on the number of texts used (1) none, 2) single, 3) multiple).

Rubric for model quality. Model quality was scored against an “expert” model of the elements and causal links in the model, as reflected across the text set. Models were scored for how many of the elements (max = 3) and links (max = 2) in the expert model that were reflected in the student’s model.

## Results

Our findings indicate that students varied in the extent to which they made use of the texts that were provided during this task. We also found a small pre/post shift from single to multiple text use for those students who made use of the texts. At pre, 59% of students used a single text, 36% used multiple (two or more) texts, and only 5% failed to use any texts. At post, 41% of students used a single text, 50% used multiple texts, and 9% failed to use any texts. This indicates that some students were more aware of the need to examine and use multiple texts than others.

Our findings suggest that students in these groups engaged with the texts in qualitatively different ways. We found that 62% of single text users at pre and 67% at post only made use of one of the two illustrations in the text set. In contrast, 62% of multiple text users at pre and 64% at post used illustrations in addition to running text, while other multiple text users (38% at pre, 36% at post) only used running text. This suggests that single text users largely relied on illustrations to create their models whereas multiple text users engaged with all aspects of the texts. We also found that only multiple text users included causal links in their models. In fact, 63% of multiple text users at pre and 73% at post included one or more causal links. In contrast, no single text users included causal links at either time point. This indicates that only multiple text users were making connections within and across texts.

We found that these variations in text use led to important differences in model quality. A one-way, between subjects analysis of variance was conducted on post-test data comparing the effect of text use on (1) number of elements (2) number of causal links for no text, single text, and multiple text groups. These analyses revealed a significant effect of text use on model quality with respect to the number of elements,  $F(2,19)=45.017$ ,  $p<.001$ , and the number of links,  $F(2,19)=9.00$ ,  $p=.002$ , that students included in their models. Planned comparisons revealed that students who used multiple texts included significantly more elements than students who used a single text,  $t(19)= 8.14$ ,  $p<.001$ , and students who used no texts,  $t(19)=6.85$ ,  $p<.001$ . Multiple text users also included significantly more causal links than students who used single texts,  $t(19)=4.03$   $p=.001$ , and students who used no texts,  $t(19)=2.35$ ,  $p=.03$ . Thus, our findings suggest that the unique ways that multiple text users engaged with the texts, particularly their engagement with all aspects of the texts and synthesis within and across texts, led to the creation of high quality models that reflect a complete, integrated understanding of the phenomenon.

## Implications

This work provides insight into the challenges associated with multiple-text processing and highlights the impact of this practice on scientific understanding. The findings from this work will be used to inform the development of curricular materials to support these critical scientific literacy practices.

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## Acknowledgments

In addition to the authors, Gina Hale and Ursula Sexton made important intellectual contributions to the design of the water cycle module. The research reported here was supported, in part, by the Institute of Education Sciences, U.S. Department of Education, through Grant R305F100007 to University of Illinois at Chicago. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.

# **Building a Learning Progression for Chromosome Segregation Using Phenomenographic Variation Theory**

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**Abstract:** Chromosome segregation is a critical yet challenging concept in genetics. Most studies on how students learn genetics has focused on the K-12 level. Here, we describe the process of building a learning progression for chromosome segregation at the undergraduate level using variation theory from phenomenography. A major finding is that students demonstrate increasing sophistication in connecting the different modes of representation of chromosome segregation used in instruction.

## **Rationale**

Chromosome segregation is a critical phenomenon in cell division and is one of the most important yet difficult concepts for students in genetics (e.g. Kindfield, 1994). Chromosome segregation provides the mechanistic explanation for inheritance and Mendel's laws, as well as a means to understand complex genetic phenomena, including recombination or crossing-over, nondisjunction, and chromosome rearrangements.

Despite much instructional effort, students have difficulty grasping the phenomenon of chromosome segregation, as reflected in their performances in diagnostic tests (Smith, Wood, & Knight, 2008). In particular, many students cannot depict the proper structure of chromosomes in mitosis and meiosis, are unable to position gene alleles in their correct positions on chromosomes, and have trouble explaining the causal relationships between errors in chromosome segregation and the outcomes of meiosis (Smith & Knight, 2012).

The central question is *how* students conceptualize the process of chromosome segregation. Only with this knowledge could we identify learning obstacles and design effective instructional interventions accordingly. Since most studies on students' learning of genetics have been focused on the K-12 level (e.g. Dukan, Rogat & Yarden, 2009), there is much need to unpack how undergraduate students understand chromosome segregation, especially the more advanced aspects of this phenomenon. Therefore, we focused our initial effort on recombination, a critical aspect of chromosome segregation in the undergraduate genetics curriculum.

## **Theoretical Approach**

This study is designed to explore how students conceptualize the process of chromosome segregation and to identify the obstacles that prevent them from learning this phenomenon effectively. As the study is exploratory in nature, the research question is left intentionally broad to capture students' wide range of conceptions.

We used variation theory from phenomenography as a theoretical framework. Phenomenography, a qualitative research methodology, investigates the various ways that people experience or conceptualize a phenomenon (Marton 1981). Variation theory offers a theoretical lens to explore the possible variations in these experiences and the learning that result from these differences (Bussey, Orgill & Crippen, 2013). Variation theory posits that each phenomenon (i.e. chromosome segregation) has defined aspects (e.g. recombination), and for each aspect, there is a limited number of features that exhibit distinguishable variations among them. Learning occurs when the different features and their variations are integrated into a coherent whole.

Variation theory can potentially be a useful theoretical framework for building learning progressions (e.g. Swarat, Light, Park & Drane, 2011). Learning progressions are descriptions of increasingly sophisticated ways of thinking about a phenomenon (National Research Council 2007). Essentially, learning progressions are conceptual pathways that students navigate as they develop understanding of a phenomenon. Defining learning progressions will provide the theoretical foundation to design instructional material that specifically targets transitions along these conceptual pathways.

## **Methodological Approach**

The method of clinical interview was employed to explore students' conceptions of chromosome segregation. Clinical interviews help researchers gain insight into student mind by involving him or her in a concrete task, asking a "how did you do it?" or "why" question, and offering an immediate hypothesis making and testing regarding the student's response (Ginsberg, 1997). The flexibility and effectiveness of clinical interviews have led to its adoption in many studies of human cognition, the most relevant of which include the famous study of how experts and novices understand physics problems (Chi, Feltovich & Glaser, 1981).

We engaged students in interview tasks derived from their midterm exam questions that involve the phenomenon of chromosome segregation and, in particular, various aspects related to recombination. Students were asked to solve these problems, while being prompted to explain their problem-solving approaches and to

illustrate their thought processes by drawing diagrams. An educational researcher trained in the research methodology led the interviews, and a content expert participated to ensure the quality of the interviews.

To capture the variety of student conceptions, we recruited students who demonstrated different levels of performance on the exam questions. That is, we included students who provided sophisticated answers representing multiple features of recombination, those who showed understanding of one or limited number of features, and those who performed poorly on the exam questions. This sampling method was chosen to increase the possibility that we witness the full variations among student conceptions.

Interviews were transcribed verbatim. Data analysis took a grounded approach, with iterative close reading of the transcripts and artifacts (i.e. student-drawn diagrams) to identify phenomenographic features of recombination and the variations among these features. Key aspects of chromosome segregation, especially in relation to recombination, were analyzed.

## Findings and Conclusions

We report here the analysis of results from six interviews. A major finding is the disconnection among different features that students used to describe the phenomenon. Students had difficulty integrating the multiple features (i.e. modes of representation) of chromosome segregation and recombination employed in instruction. For example, Students with low performance on the exam typically recognized recombination of genetic material in offspring in one of three ways: conceptual (i.e. phenotypic differences from parents), mathematical (i.e. defined frequency from crosses), or symbolic (i.e. genotypic combinations of alleles). Students with increasing performance, and potentially increasing sophistication in understanding chromosome segregation, described the aspect in two or all three features.

We believe that these preliminary findings and our approach can shed light on possible ways to build a learning progression for chromosome segregation and recombination in particular. Ultimately, we anticipate that this study will yield an outcome space of different student conceptions of chromosome segregation. This outcome space will define a learning progression, including descriptions of varying levels of conceptions, key features that differentiate among the levels, and possible obstacles that prevent students from advancing toward more sophisticated understanding.

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# **Tools for Sustained Student Engagement in InterLACE (Interactive Learning and Collaboration Environment)**

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**Abstract:** This poster documents the important role that CSCL technologies like InterLACE can play in providing spaces for active learning, reflection and social discourse, and thereby sustaining student engagement. We present a suite of tools designed to support sustained student engagement in InterLACE (Interactive Learning and Collaboration Environment), an online collaboration environment designed to support STEM education. We include tools designed for use by researchers, teachers, and students that provide insight into vocabulary usage, participation rates, and collaboration patterns. Preliminary results from six classrooms will be presented.

## **Major Issues, Theories, Significance**

Science, technology, engineering, and mathematics (STEM) education has experienced a philosophical shift away from the memorization of facts, figures, and procedures toward engaging students in more authentic science practices. Central to this practice-and-process focus is a multi-dimensional concept that we call “active and sustained learner engagement”: the interaction of higher order cognitive engagement, motivation, and interaction among peers.

Sustained learner engagement requires assessments that are “concurrent, embedded, and integral to the teaching and learning process” (Chan & Lee, 2007; Black & Wiliam 1998). Increasingly new technologies can play an important role in helping teachers blend authentic scientific inquiry and formative assessment. Few efforts have been made to develop systems that help teachers understand their students’ activity and learning as it happens (Shapiro & Wardrip, 2011). Researchers have only just begun to examine how the use of CSCL tools for formative assessment support teachers in addressing student learning needs as they evolve in the classroom in the moment of instruction across different kinds of pedagogies (van Es and Sherin, 2001). As well, beyond feedback on multiple choice type questions, even fewer tools are available to help students both incorporate and benefit from formative assessment data.

InterLACE (Interactive Learning and Collaboration Environment) is an innovative web-based computer supported collaboration environment that encourages scientifically meaningful experiences and promotes a broad range of active learning processes including epistemic practices of disciplines, authentic science practices as defined by the Next Generation Science Standards, and sustained engagement.

We have developed a suite of tools within InterLACE designed to measure and support this multi-dimensional concept of active learning and sustained student engagement by building on earlier work on formative assessment tools by Teplovs, Donoahue, Scardamalia and Philip (2007). The suite comprises three core toolsets, each of which is designed to answer one of the following questions: (1) What are students writing about? (2) How much are students contributing? (3) Who is working with whom?

The interplay between the three factors that these questions address provides a framework for understanding and maintaining active learning and sustained engagement. The use of multiple tools provides for a degree of internal triangulation and checks of validity. Our goal is to extend this approach to provide a deeper understanding of the dynamics of learner engagement. If we can deploy analytics that tell us about all three factors, teachers should be in a position to design learning activities that are both challenging and personally engaging. And if students are writing about deep concepts, with posts and responses that continue over time, and are interacting with one another’s ideas, then it may be more likely that student engagement and personal growth will remain high.

## **Preliminary Findings**

We will present data from six classrooms. Single-class examples of the analyses that will be conducted across all classrooms are shown in Figure 1, which highlights three of the tools from the toolset. The vocabulary growth tool (Figure 1a) shows vocabulary growth over time, which is related to contribution rates (Figure 1b). Collaboration patterns are available in graphical and textual form (Figures 1b and 1c). We believe that the key to maintaining sustained student engagement is the interaction between these three metrics. However, each question can also be considered independently to provide insights about student activity.

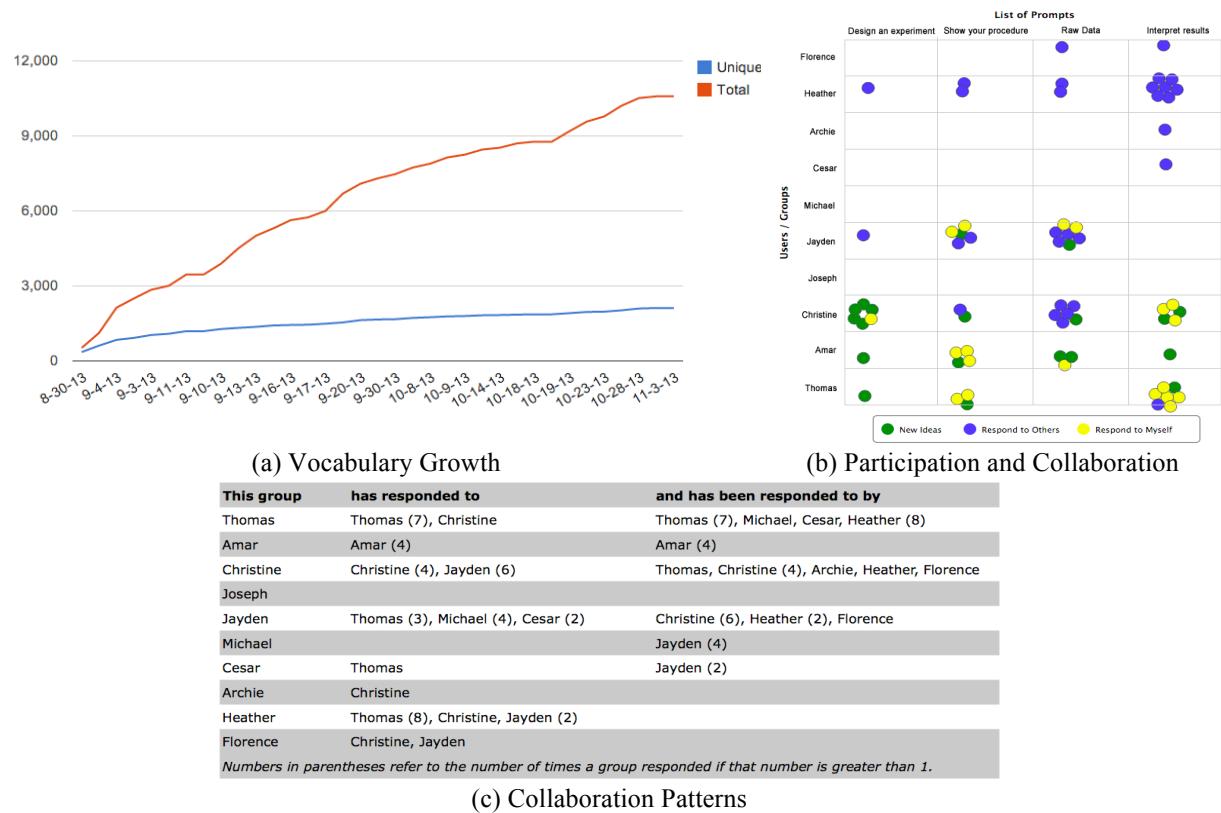


Figure 1. Analysis Tools.

Investigations into word use by students within their posts shows continued substantial gains in vocabulary growth over time both in terms of total words and unique words used within the class, from the perspective of all words (Figure 1a), academic words, and domain-specific words (i.e. words about the topic of physics). Measures of productivity are also important, and this toolset counts contributions over time by students including original posts, responses to others, and self-responses (Figure 1b). Visualizing this information provides the teacher and students instant access to not only the type and quantity of activity happening within the system, but also the nature of the interactions and the dynamics of the community of learners (which students are/aren't participating and which part of the lesson is generating the largest number of ideas and discussion). In addition, understanding the details of student responses to ideas (of their own or of their classmates) can provide high-level information into the nature of collaboration. Beyond the table information presented to the class (Figure 1c), we also look at the details of who is collaborating with whom by examining the associated social networks generated by the class over time within the system.

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# **“Are You ‘In’ or Are You ‘Out’?” Investigating the Factors Affecting Immersion in a Location-Based AR Game for IBSE**

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**Abstract:** It is argued that augmented reality games can promote immersion and feelings of presence, which could support students' engagement with the learning process. Sustaining presence is crucial but challenging, since immersion is a transient state. As part of a broader design-based research, in this study, we employed a focus group methodology to investigate the perceptions of eighteen 11th graders regarding the factors which affected their immersion during an augmented reality game for inquiry-based science learning.

## **Introduction and Theoretical Framing**

There is a wide-spread assumption according to which immersive Augmented Reality (AR) games could result to feelings of presence within the game, as a sense of being there. Dede (2009), who defined immersion “as the participant’s suspension of disbelief that she or he is ‘inside’ a digitally enhanced setting” (p.66), argued that immersive games could increase students’ engagement with the learning process. In recent years, we have witnessed a rapid increase in the number of location-based AR games for inquiry-based science education (IBSE). These games respond to the gamer’s position and augment physical landscapes with digital information, thus allowing students to explore the natural environment around them by using mobile technologies (Cheng & Tsai, 2013). However, despite the potential of these games, student immersion and sense of presence should not always be taken for granted. McCall, Wetzel, Löschner and Braun (2011) concluded that sustaining the players’ sense of presence at high-levels is challenging, since presence requires that students are fully immersed in the experience during the full AR experience. According to Reid, Geelhoed, Hull, Cater and Clayton (2005), this challenge could be attributed to immersion being a transient state, since players in AR games move constantly between immersive and non-immersive states, highlighting the need for further investigation of the factors that may affect or sustain immersion. Considering that there is a lack of studies investigating this issue explicitly, the present study focuses on the AR gaming experience of high school students who participated in an intervention involving a location-based AR game for IBSE.

## **Methodology**

A total of eighteen 11th graders played the “Trace Readers”, a location-based AR game we designed for the purpose of this study. The AR experience lasted approximately 2 hours; according to the scenario, students were asked to work in pairs sharing a tablet, in order to investigate an authentic environmental science problem regarding the decline of the mallard duck population at the lake. In order to accomplish their mission, students had to visit several stations by the lake and gather information from several game-based characters on different aspects of the problem. As part of a broader design-based study seeking to investigate what immersion is and how it is related to students’ learning, we collected data on students’ perceptions of immersion through two semi-structured focus groups, each of which lasting for 1.5 hours. Questions aimed at prompting the students about issues of immersion, asking them, for example, to express whether they were feeling as being more in the game world or in the real world while playing the game. The data were qualitatively analyzed, using the Attride-Stirling’s (2001) thematic network analysis to identify perceived factors of immersion. In other analyses, which are still under way, we are also examining videotapes of students’ discourse during the AR game to investigate student engagement and triangulate findings.

## **Results**

The qualitative analysis employed resulted in the categorization of the factors discussed in four different aspects influencing students’ immersion: (a) the user interface, (b) the narrative employed, (c) the gaming space and (d) unforeseen distractions (see Table 1). Relating to the user interface factor, students positively evaluated the use of an application with a user friendly interface, in order to augment the real world. They negatively evaluated the cartoonish graphics and game-based characters, as well as the text-based information provided, indicating the need for more realistic graphics and characters as well as for the replacement of text-based information with more multimedia content. Moving to the narrative factor, students expressed that since the narrative was structured around a problem-based investigation and included a diversity of data this contributed to their immersion, as they had to investigate and to connect several pieces of data in order to solve the mystery. In addition, students mentioned that they felt a sense of competition, explaining that this made the game more

challenging. As students also indicated, some of the gaming challenges in this narrative were not demanding enough and on occasions the plot lacked surprises; in these cases, students reported that their immersion was decreased. Another point made was that since informational data were provided by the game-based characters, there was a lack of agency, which hindered students' immersion. Where the gaming space factor was concerned, students emphasized the location-aware nature of the game that allowed them to be immersed in and enjoy the natural environment. Nonetheless, the students emphasized the need for a greater coupling between the physical and the virtual world, through the combination of both digital and real artifacts, for the creation of a more immersive augmented reality space. In addition, students disliked the hotspots' circular arrangement by the lake, explaining that they would like to follow a more challenging and complex path of inquiry. Finally, students reported on a number of unforeseen distractions that interrupted their immersion such as the hot weather, screen glaring due to the sunlight, environmental distractions, external noises or technical problems.

Table 1: Categorization and evaluation of factors discussed as affecting immersion.

Theme	Basic themes	Evaluation	Frequency
User Interface	User-friendliness of interface	+	42
	Realism, animation and interactivity of graphics	-	22
	Realism and fidelity of game-based characters	-	32
	Text-based information	-	37
Narrative	Problem-based investigation	+	34
	Diversity of data	+	44
	Competitive nature	+	10
	Level of challenge	-	25
	Agency and first-person perspective	-	17
	Gaming plot	-	18
Gaming space	Nature-based location	+	33
	Mobility and location aware nature of the game	+	8
	Balance between the physical and virtual world	-	23
	Hotspots' arrangement	-	24
Unforeseen distractions	Weather	-	72
	Technical bugs	-	19
	External noises	-	18
	Environmental distractions	-	14
	Screen Glaring	-	8

## Conclusions

There is a wide-held assumption that location-based AR games may afford immersive experiences as well as a sense of presence in the game, which are related to desirable learning behaviors (Cheng & Tsai, 2013). However, immersion is a transient state, provoking a fluctuation in the sense of presence (e.g. McCall et al., 2011; Reid et al., 2005). The present study investigated the factors which high school students reported as promoting or hindering their immersion with a location-based AR game for IBSE. Several factors relating to the user interface, the narrative, the gaming space or unforeseen distractions have emerged as affecting students' immersion. Our future work will attempt to triangulate these findings by analyzing students' AR actions and discourse in an attempt to understand students' feelings of presence and how to sustain students' engagement with the learning process.

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# **Collaborative Hypothesis-Building Using Immersive Virtual Environments for Ecosystems Science**

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**Abstract:** EcoMUVE is a middle school science curriculum in which students explore an immersive virtual ecosystem and learn its causal dynamics through collaborative inquiry activities. Students work in teams of four to construct hypotheses about the relationships in the virtual ecosystem, using as evidence the data and observations collected through their virtual experiences. An analysis of the audio files of four teams demonstrates the ways in which their learning processes are situated within the virtual world.

## **Introduction**

EcoMUVE (<http://ecomuve.gse.harvard.edu>) is a curriculum for middle school students to learn about complex causal relationships in ecosystems simulated by Multi-User Virtual Environments (MUVEs). EcoMUVE supports situated learning, in which students learn through being immersed in a richly represented ecological setting. Students work in teams to observe the environment, collect physical, chemical, and population data, and talk to digital characters, in order to solve a virtual mystery. This study articulates how students' experiences in this context aid in their collaborative concept mapping activities.

Student engagement in scientific practices is a central theme in the Next Generation Science Standards. Integral aspects of scientific practice include understanding the nature of evidence, using scientific arguments, and interpreting data related to scientific claims (Achieve 2013). The literature on collaborative concept mapping has found that this representational structure shows promise as an effective mechanism to support students constructing representations of their conceptual understanding, as well as fostering sustained small-group discussion about scientific ideas and deeper understanding through discourse and evidence-based arguments (Novak, 1990; Roth et al., 1994; Sizmur & Osborne, 1997).

Multi-user virtual environments (MUVEs) have been demonstrated to be useful tools for science education (e.g., Barab et al., 2005; Clark et al, 2009; Ketelhut et al., 2010). In the design of EcoMUVE, we draw on Reiser's (2004) characterization of scaffolding by software tools, which can support learning by structuring the learning task, and drawing student attention to important aspects of the phenomena being represented and key questions to solve. MUVEs can provide scaffolding through visualizations that highlight salient features, can simulate data collection and analysis tools, and can display multiple representations of phenomena (for example, scientific processes represented at both macro and micro levels). These design features are intended to facilitate student learning and to draw attention to important aspects of the phenomena being represented.

## **Methods**

EcoMUVE Pond is a two week, inquiry-based curriculum unit centered on a virtual pond and the surrounding watershed. Students explore the pond and its biodiversity, and travel in time to see changes over the course of a virtual summer. They discover a fish kill, and are tasked with figuring out why it happened. Students make observations, shrink to view microscopic organisms, and track individual atoms. They collaborate in teams to collect and share water, weather, and population data, as well as to graph changes in the data over time. They construct and present to the class an evidence-based concept map that represents their hypotheses of the ecosystem relationships. To look at students' collaborative hypothesis-building, we conducted a case study of a teacher and four classes of 7th grade students, ages 12-13, while they used the module. One team in each class was randomly selected to be audiotaped for 4 days during their collaborative activities (N=16).

## **Findings**

### **Facilitated Observations and Inferences via Situated Learning in the Virtual World**

Students perform observation and data collection tasks while immersed in the MUVE. In this example, students easily travel in time, and attend to salient visual features of the ecosystem:

S3: Guys, on July 6th it's raining. I don't know if that has to do with anything, about like the nitrates and phosphates.

S1: Record that. Record it was raining. Cause that makes things grow. And the water, just by looking at it, it looks green.

S2: Yeah, it got disgusting.

S1: On August 15, too, it's pretty bad.  
S3: Yeah, it has a lot of chlorophyll.

### Multiple Forms of MUVE-Based Evidence Used in Constructing Hypotheses

Types of evidence students used from the MUVE included *perceptual information* (e.g., noticing the pond turning green, above), *data* viewed in tables and graphs, *reference tools* such as the atom tracker or online field guide, and *testimony* from characters in the world. In this example, students draw from all of these:

S5: Oh you guys! When I was tracking carbon... On the 10th, there was a lot of bacteria, and on then 16th they took in oxygen. So I think that's also why some of the fish died because if there is an increase number of bacteria on the 28th they're taking in even more oxygen which is also making the fish die. And also the minnows eat a lot and so that was a lot of oxygen and they're giving out a lot of carbon dioxide and minnows tend to eat small things like bacteria and algae so ...

S6: Yeah. What about the guy with the fertilizer? Do you think it could have run off the golf course? Wait, the day before the 28th - I think it was the 25th, the day before the 28th that you were allowed to measure - it was raining and that guy had the fertilizer and was putting it on the golf course and maybe the rain washed the fertilizer down into the lake and that killed all the fish!

### Collaborative Hypotheses with Concept Maps and MUVE-Based Evidence

Students' final concept maps were part of a group poster that included a written description of their hypothesis, and printouts of evidence from the world. Figure 1 shows one group's poster, which includes printouts of graphs and tables, as well as "our key piece of evidence" printed from the in-world field guide.

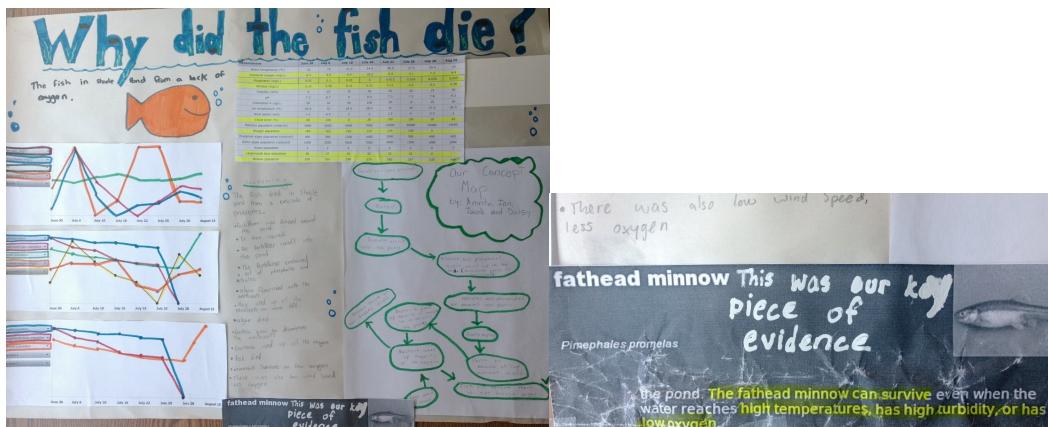


Figure 1. Student poster and example of evidence.

### Discussion

EcoMUVE places students in a richly immersive context with many learning resources. Findings presented here suggest EcoMUVE scaffolds student use of perceptual information, data, reference materials, and testimony in service of building collaborative explanations of ecosystems phenomena represented in the virtual environment.

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# **Understanding Data Variability in Ecosystems: Blending MUVE and Mobile Technologies to Support Reasoning with Real World Data**

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**Abstract:** Inquiry-based instruction is a focal point of recent research and Next Generation Science Standards, but students have difficulty connecting evidence to claims, especially when data are highly variable. We explore a blended curriculum that supports inquiry activities in a virtual world, followed by inquiry activities in the real world with first-hand collection of authentic, variable data supported by mobile devices. This study characterizes how students use and interpret data across these two instructional contexts.

## **Introduction**

Both research findings and the Next Generation Science Standards advocate for using inquiry-based instruction to reach learning goals related to science content, practices and understanding the nature of science (Wilson, Taylor, Kowalski, and Carlson, 2010; Achieve, 2013). At the same time, it is recognized that careful scaffolding of inquiry activities (Quintana et al., 2004; Hmelo-Silver et al., 2007) and reflection upon scientific practices (White & Frederiksen, 1998) are necessary to reach these learning objectives. Here we report on a pilot project in which we use a multi-user virtual environment (MUVE) in the classroom and augmented reality experiences during a field trip to scaffold student engagement in inquiry activities and to promote reflection on the role of variability in data collection, synthesis, and interpretation.

Across domains, students have difficulty relating evidence to claims (e.g., Krajcik et al., 1998), and this problem can impede students' attempts to meaningfully connect inquiry activities and science concepts. This is a particular challenge in the field of ecosystem science, because (1) the temporal and spatial scale of observable patterns in ecosystems are difficult to represent within the bounds of classroom instruction, and (2) environmental data tend to be inherently "messy" – meaning that it may be difficult to detect the ecologically-relevant signal among the noise, or variability, in the data. While first-hand data collection has been shown to promote student motivation (Hug & McNeill, 2008), students struggle to reason using data in which variability from both measurement error and meaningful natural processes plays an important role (Kanari & Millar, 2004). Thus, evidence of ecosystem phenomena is difficult for students to apply for scientific reasoning.

In this study, we explore a blended approach in which students begin with a structured classroom experience conducting inquiry activities with a fixed and simplified data set (EcoMUVE), followed by mobile broadband device supported inquiry activities in the real world with first-hand collection of highly variable data (EcoMOBILE). Augmented realities (AR) for learning utilize mobile, context-aware technologies (e.g., smartphones) that enable participants to interact with digital information embedded within the physical environment. The AR technology supports extending student learning by allowing field data to be more easily shared and analyzed back in the classroom. We show how students' experiences across these instructional contexts enhance their ability to make sense of messy real world data.

## **Methods**

EcoMUVE and EcoMOBILE provide complementary exposure to data and variability in the context of a larger inquiry problem. EcoMUVE (<http://ecomuve.gse.harvard.edu>) is a two-week immersive virtual ecosystem representing a pond and its surroundings. Students explore the pond via avatars, traveling in time over a virtual summer, and discovering a fish kill. Working in teams to solve this mystery, students collect data on water measurements such as temperature, dissolved oxygen, phosphates, pH, and turbidity, explore at microscopic and even atomic levels, and use tables and graphs to view and analyze data over time.

EcoMOBILE (<http://ecomobile.gse.harvard.edu>) provides a complementary experience to the use of EcoMUVE in the classroom because students have an opportunity to apply their ideas about pond ecosystems during a field trip to a local pond. EcoMOBILE employs two technologies: MBDs (mobile broadband devices) running augmented reality software and note-taking applications, and probeware to collect measurement data.

The pilot study included one teacher and four classes (N=90) of seventh grade students from a suburban school district in the northeastern U.S. Students worked with the EcoMUVE curriculum during a two-week period, followed by one week of experiences associated with EcoMOBILE, including the pond field trip. Research data collected for this study included video and audio recordings of students, worksheets, and pre-post surveys around the EcoMOBILE portion of the activity. Students worked in pairs to collect data measurements – temperature, dissolved oxygen (DO), or turbidity. They chose measurement locations around the pond, documenting the spots using Evernote. Map and number line visualizations prompted students to compare and

reflect on reasons for different measurement results. During post-field trip class discussion of data, notes and photos, students shared hypotheses about the variations they had observed.

## Findings

*Pre-post survey:* The pre-post survey, pre-administered after EcoMUVE but before EcoMOBILE, and post-administered after EcoMOBILE, included questions related to interpretation of variability. Students were presented with two similar questions involving hypothetical variable dissolved oxygen (D.O.) data from a pond. Within EcoMUVE, students observed D.O. measurements between 4mg/L to 10.2 mg/L. The survey items contained three data sets with measurements in this range (between 7.2 to 8.8 mg/L) and a fourth data set that ranged from 22.9 to 23.1 mg/L, values that are far outside the normal range. After selecting a closed-response option, students were asked to explain their reason for choosing that option. When considering small differences between two data sets, students' written explanations shifted to include significantly more ecological mechanisms (paired t-test,  $p = 0.032$ ) that could contribute to the observed differences, like decomposition, plants, and water depth. When considering a data set with large differences, a marginally significant number of students (paired t-test,  $p=0.06$ ) used personal experiences to help explain the observed differences.

*Field trip experiences:* Brief field interviews indicated that students had many ideas about the reasons for variation they observed in the field, identifying factors like sunny or shady spots, depth of the probe, and muddiness of the water. They also made distinctions between slight or insignificant variations, compared to larger, significant differences. For example, one student described a cluster of shady-location temperature measurements ranging from 14-16°C as "all pretty much the same," then pointed at the map to show a higher measurement of 20°C "over here where I think there's more sunlight."

*Post-field trip discussion:* Looking at the combined class data in the classroom, students commented on clusters and outliers in the number line, and groupings on the maps. Students recalled and felt connected to their experience, sharing details of their collection experience. Students' photos and notes were highly useful in contextualizing the data; for instance, students noticed in temperature photos whether the location was sunny or shady, or whether the spot was insulated by fallen autumn leaves.

*Prior EcoMUVE experience:* In post-discussions, students' hypotheses frequently referred to concepts highlighted in EcoMUVE, which grounded their understanding of processes such as photosynthesis and decomposition. One student said that "photosynthesis can produce oxygen in the water and I got the 12.5 right on the bottom right corner there and that was a more plant filled area." Another student suggested that "all the leaves blew over to there, so that means they will decompose and bacteria and cellular respiration."

These initial findings suggest that students were applying ideas about variability to the data they had collected and were able to connect their claims about the cause of variability with reasoning that included knowledge they had gained through using the EcoMUVE curriculum in the classroom. This study offers initial support for the idea that using a blended curriculum that scaffolds inquiry activities, situates variability in personalized, real-world contexts, and offers structured exposure to increasingly variable data can aid student ability to connect evidence to claims.

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# Identifying Affordances of 3D Printed Tangible Models for Understanding Core Biological Concepts

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**Abstract:** 3D models derived from actual molecular structures have the potential to transform student learning in biology. We share findings related to our research questions: 1) what types of interactions with a protein folding kit promote specific learning objectives?, and 2) what features of the instructional environment (e.g., peer interactions, teacher involvement) affect learning? We provide a framework for categorizing ways of using the models that can be used as evidence for whether and how physical models promote molecular understanding.

## Introduction

Many studies have reported that core ideas in molecular biology are difficult for students to understand (e.g., Hildebrand 1991; Longdon, 1982). Molecular biology requires students to understand processes at multiple levels from the sub-microscopic (e.g., atoms) to microscopic (e.g., proteins, genes, chromosomes) to larger structures (e.g., organelles, cells, and organs). Because students have no direct experience with molecular components or processes, the coordination of these levels is particularly challenging (Kindfield, 1994). Students have difficulties mapping structure, function, and emergent processes, fail to make important connections, and develop misunderstandings of the mechanisms involved in biological processes (e.g., Duncan et al., 2009; Lewis & Wood-Robinson, 2000; Marbach-Ad & Stavy, 2000).

Tangible models that allow researchers to “think with their hands” play an essential role in many significant scientific findings. In molecular biology, Pauling used models to predict the basic folding units of protein structure, and Watson and Crick used models to identify the structure of DNA and reconcile decades of genetic data. In the current project we investigate whether and how an innovative protein folding model developed at the Scripps Research Institute promotes understanding of core concepts in molecular biology, including handedness and how structure determines the function of a protein.

The protein folding kit has numerous advantages over traditional “ball and stick” models (see Figure 1). Typical models are limited to simple chemical structures, making them unsuitable for modeling complex biological molecules, and cannot be easily used to represent dynamic processes such as protein folding. In contrast, the protein folding kit realistically models features of biological molecules such as their shape and flexibility for function and interaction. Typical “ball and stick” models have no affordances for assembling “correct” molecules as they have generic slots for fitting together atoms or molecules. Students can create erroneous models as easily as accurate models. Finally, typical models require students to follow complex directions to assemble structures. The protein folding kit has affordances that allow the models to assist in their own assembly, guiding students to create models based on natural interactions. Forces between embedded magnets represent molecular attraction and repulsion. The magnets allow students to use these forces to engage in the process of folding a protein from the primary structure, a long chain of amino acids. Students are able to observe the model’s emergent properties as they discover the nature of the folding process.



**Figure 1.** The protein folding kit. Top left and bottom right show primary structures of chains of amino acids. Top right shows secondary structure of helices. Bottom left shows tertiary structure of complete folded protein.

In the current study we explore the affordances of the innovative protein-folding model and focus our investigation on two research questions: 1) what types of interactions with the model promote learning?, and 2) what features of the instructional environment (e.g., peer interactions, teacher involvement) affect learning?

## Data Sources and Analyses

To explore the affordances of the protein-folding model, we carried out observations in a graduate course in structural biology at The Scripps Research Institute. Researchers videotaped two sections of the course, in which 14 students participated in a lab practical to explore and build a model of a folded protein. Students worked in groups of 3-6 students while instructors circulated to ask and answer questions and ensure students were on task. Students started with the primary structure, the backbone of a strand of amino acids, then built secondary structures (helices and beta sheets), and finally built the tertiary structure, the folded TIM barrel protein (see Figure 1). The learning objectives were: 1) to understand how the handedness of the primary structure influenced the handedness at the other levels of structure, and 2) to understand how hydrogen bonds allow for stability in common secondary structures (beta sheets and helices).

All video recordings were transcribed. Preliminary coding identified which features of the tangibles students attended to (e.g., the magnets, the peptide chains), what concepts were mentioned (e.g., molecular structure and self-assembly), what processes were carried out (e.g., how students attempt to fold the protein, what strategies they use to complete the task), and what explanations were generated (e.g., “those proteins don’t fit together because they have different shapes”).

## Preliminary Findings

All student groups were successful in ultimately building the completed protein model. Preliminary coding identified three main types of interactions with the model that appeared to help students make connections between the model building exercise and fundamental concepts in molecular biology. The interaction types identified were labeling, building, and testing. This first activity, labeling, is the process by which students map the parts or structures of the model to scientific terminology. E.g., the force between magnets represents a hydrogen bond. Labeling allowed students to make connections between the model and course content. Building is the process of students using the model to learn about the interactions between pieces and the resulting spatial structures. For instance, students made bonds to form three types of helices. The activity of building provided a deeper encoding of the structures of molecules as students learn using multiple modes of processing (auditory, visual, and touch). Finally, testing refers to using the tangible model for conducting scientific inquiry and generating explanations. E.g., students tested how folding secondary structures impacted the overall stability of the protein. We postulate that the activity of testing helps students develop a schematic understanding of the science system as they generate causal inferences from their interactions with the models.

Preliminary findings of classroom features suggest engagement with instructors who provided prompting questions significantly contributed to learning, as interactions with instructors generated a greater number of relevant questions than students working alone. We anticipate our continued analyses will reveal additional features of the instructional environment that affected learning. Though our results are in the context of this particular model, we anticipate that the findings will generalize to other domains and provide important insights into when and how tangible models can be used to promote conceptual understanding in science.

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## Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant DRL-1108896, PI Davenport, and the Institute of Education Sciences, U.S. Department of Education, through Grant R305A120047 to WestEd. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation, the Institute of Education Sciences, or the U.S. Department of Education.

# Comparison of Specific and Knowledge Integration Automated Guidance for Concept Diagrams in Inquiry Instruction

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**Abstract:** This study compares two types of automated adaptive guidance for concept diagrams to improve middle school students' science learning in web-based inquiry instruction. Specific guidance tells students precisely what to improve, while knowledge integration guidance suggests revisiting a specific visualization to locate useful information. The results suggest that knowledge integration guidance is more effective in helping students distinguish among multiple ideas and develop more coherent views than specific guidance.

## Introduction

Formative guidance plays an important role in improving inquiry learning (Shute, 2008), but many teachers often lack the time or resources to provide appropriate guidance to individuals (Ruiz-Primo & Furtak, 2007). Advances in automated scoring technologies can help teachers by providing timely and flexible guidance on individual responses in a variety of web-based settings, but the design of effective automated guidance remains underexplored. Most automated guidance is specific, identifying incorrect ideas or providing correct answers on problems (Chase & Houmanfar, 2009). This type of guidance could help students fix their responses, but it may encourage students to change their answers without improving their understanding of the concept. Designing guidance that promotes inquiry processes could support students in distinguishing the newly acquired ideas from their initial views to formulate a more coherent understanding of complex scientific processes. For instance, guidance that suggests ways for students to improve their work, such as by pointing to a helpful resource, can prompt students to actively identify gaps in their knowledge and search for relevant information to revise their work (Chi et al., 2001). In this study, we compared specific guidance to inquiry-oriented guidance aligned with knowledge integration (Linn & Eylon, 2011) to help middle school students revise student-generated concept diagrams and improve their understanding of energy flow in life science in web-based inquiry units.

## Methods

202 students from eight 7<sup>th</sup> grade classrooms were assigned to either a *specific* guidance (N=109) or a *knowledge integration (KI)* guidance condition (N=93). They worked in pairs for 13 days on two web-based inquiry units on photosynthesis and cellular respiration. Designed following the knowledge integration framework (Linn & Eylon, 2011), the web-based units consist of inquiry activities that help students develop an integrated understanding of energy flow in life science (Ryoo & Linn, 2014). Before, immediately after, and three months after the study, all students individually completed pre-, immediate post-, and delayed post-tests online. 30 students who missed one or more tests were excluded from our analyses.

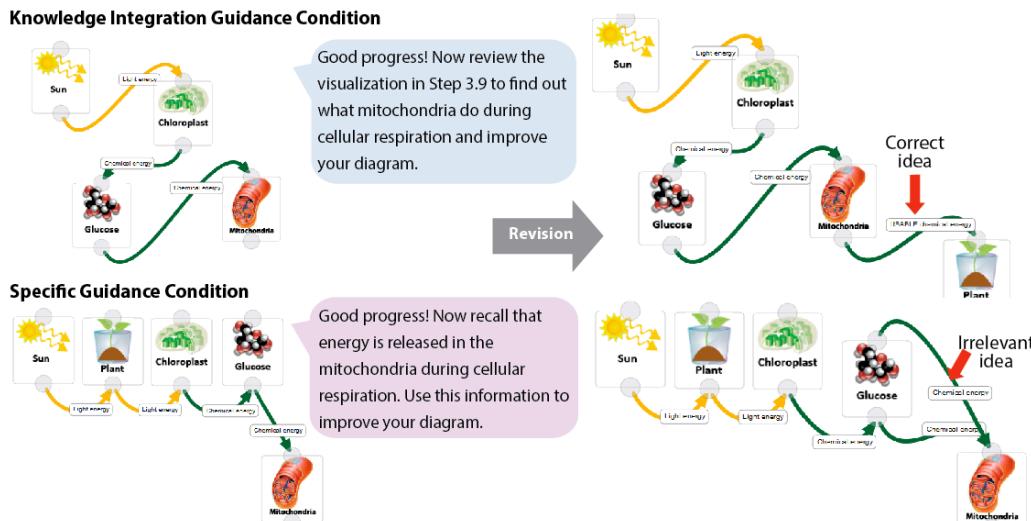
At the end of the second unit, students were asked to create a concept diagram showing how plants get and use energy from the sun using a computer-diagramming tool called MySystem (Ryoo & Linn, 2014). This formative assessment activity requires students to make connections among various energy concepts to demonstrate their integrated understanding of how energy flows in life science. Once students submitted a diagram, MySystem immediately generated automated adaptive guidance based on scientifically valid connections among core energy ideas in students' responses and encouraged students to revise their diagram. The specific guidance identified precisely what to improve in the diagram, whereas the KI guidance suggested going back to a relevant visualization step to locate the evidence needed to improve the diagram (see Figure 1).

## Results and Discussions

We scored each pair's initial and final diagrams using a KI rubric designed based on elaborated links among normative energy ideas. To examine the effects of specific (pair n=55) and KI guidance (pair n=47) in helping students revise their concept diagrams, we compared the two conditions' final diagram scores using an analysis of covariance (ANCOVA), taking their initial diagram scores as a covariate. The results revealed a significant main effect of condition,  $F(1,99)=6.64$ ,  $p<.05$ ,  $\eta_p^2=.06$ , indicating that the KI group performed significantly better on the final diagrams than the specific group. More specifically, 70.2% of the KI group took advantage of the guidance to add target energy concepts and successfully improved their depiction of energy flow. However, 52.7% of the specific group did not make any changes that led to improved understanding. Although specific guidance told students exactly which energy ideas to add or fix, students still had to determine how to visually represent those ideas using icons, colors, and labels in their diagrams (see examples in Figure 1).

To better understand why KI guidance was more successful than specific guidance, we analyzed each

pair's log data. We focused on how they used the guidance to revise their diagrams. As expected, the KI group (74.5%) was more likely to revisit visualization steps, as recommended in the guidance, than the specific group (3.6%),  $F(1,100)=117.04$ ,  $p<.001$ ,  $\eta_p^2=.54$ . Despite the recommendation, 25.5% of the KI group revised their diagram without revisiting. When comparing students who revisited and did not revisit visualization steps in the KI condition, we found a significant effect of revisiting visualizations,  $F(1,44)=4.47$ ,  $p<.05$ ,  $\eta_p^2=.09$ , indicating that students who revisited made higher learning gains than those who did not. This suggests that KI guidance encouraged students to revisit visualizations to reintroduce important key concepts, which allowed students to identify gaps in their initial understanding and actively search for useful information to improve their work.



**Figure 1.** Initial and Final Diagram Examples of Two Pairs by Condition.

To examine the effects of specific and KI guidance on individual students' learning, we conducted ANCOVA on the immediate and delayed post-tests with pre-test scores as a covariate. The results revealed a significant effect of condition for both the immediate,  $F(1, 169) = 8.92$ ,  $p < .01$ ,  $\eta_p^2 = .05$ , and delayed post-tests,  $F(1,169)=5.44$ ,  $p<.05$ ,  $\eta_p^2=.03$ . The KI group demonstrated a significantly more durable understanding of energy flow in life science than the specific group by connecting multiple energy concepts. Benefits of revisiting visualizations were also observed on the immediate post-tests,  $F(1, 79) = 6.76$ ,  $p <.05$ ,  $\eta_p^2 = .08$ . Students who revisited visualizations in the KI condition continuously performed better on the post-tests than those who revised their diagrams without revisiting the visualization steps. However, the difference between the two groups was not statistically significant on the delayed post-tests,  $F(1,79)=2.37$ ,  $p=.13$ ,  $\eta_p^2=.03$ .

## Conclusions

This study shows the value of automated adaptive guidance that promotes inquiry processes for students and clarifies how middle school students took advantage of such guidance to improve their work, compared to specific guidance. The results of the study suggest that knowledge integration guidance can serve students learning by encouraging them to diagnose problems with their responses and use evidence from the unit to revise their work. This study offers promising directions for the design of automated guidance that can encourage students to autonomously sort out their ideas and improve their science learning.

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# Elementary Students Becoming Engineers through Practice

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**Abstract:** As part of an efficacy study of elementary school engineering curricula, we are recording all engineering lessons in 24 classrooms. Data collection is split between the treatment and comparison curriculum, and will continue through June 2014. Our observation notes and preliminary video analysis suggest that some students self-identify as engineers, while others do not. Our poster will present an analysis of the contexts and contributing factors leading to students' adoption of self-concepts in engineering.

## Introduction

This poster will present a subset of findings from the first of two years of data collection for the Exploring the Efficacy of Elementary Engineering (E4) study, an NSF-funded efficacy study of an elementary engineering curriculum. Data includes work samples, teacher surveys and logs, and assessments from students in 351 classrooms, together with intensive video data collection from a subset of 24 of these classrooms.

Two different engineering curricula embodying different approaches to teaching engineering are being implemented, with random assignment at the school level. In the treatment curriculum, students are presented with a challenge through the context of a story about a child with a problem to be solved. Students are encouraged to think of themselves as engineers, and scaffolded to engage in problems the way an engineer would: for example, in studying structures, the teacher models how to analyze forces on the structures as well as how to brainstorm and test ways to counter those forces. In the comparison, students are presented with information about engineering and the challenge, and given the challenge to solve, without further context: for example, before trying to build a structure, they are given an informative text and pictures of sample structures.

The focus of this poster will be student interest in engineering and the development of an engineering self-concept. We will combine our findings from analysis of the video case studies with student work samples, an assessment of student conceptions of the field of engineering, and a survey of student interest in and attitudes towards engineering—as a topic of study, as a field, and as a possible future career.

## Theoretical Framework

The treatment curriculum is designed to engage children and teachers in meaningful activity. Its design is grounded in the learning sciences; research from these fields indicates that students learn concepts and skills through experience as they work and learn in rich contexts (Bruner, 2004; Lave & Wenger, 1991; Rogoff, 1990). The treatment endeavors to build a network of connections as the contextual basis of every unit: each unit is set in a real-world and career context; children are invited to “be engineers” as they learn about engineering practice in a particular field because learning is more profound with engagement in realistic disciplinary practices (Roth, 1994; Sawyer, 2006) that include the social and epistemic practices of a discipline and put key concepts into productive use (Duschl, 2008; Duschl & Grandy, 2008; Engle & Conant, 2002). Each unit of study ties in to literacy, social studies, science, and mathematics. In every unit, children are invited to reflect upon and build their own understanding through experience with materials, inquiry, and design, and their knowledge of the world. By engaging in activities that afford reflection on—as well as productive use of—their experience and understanding of science, students are more likely to learn and retain their understanding (Kolodner et al., 2003; Zubrowski, 2002). Lessons are designed to scaffold student learning through teacher questioning, through lesson plans that make disciplinary strategies explicit and encourage students to express and reflect upon their learning (as recommended by Quintana et al., 2004), and through complex activities supported by structuring of problem-solving processes (as recommended by Hmelo-Silver et al., 2007).

The comparison curriculum is primarily drawn from engineering lessons and activities freely available on the internet, featuring both direct instruction and a hands-on component. A few lessons were designed from scratch to match learning objectives featured by the treatment curriculum, for which no available existing lessons were found. The found lessons have been modified to be more strongly appropriate for grades 3–5—most were specified as appropriate for grades 3–12; also the “direct instruction” aspects of the curricula have been improved as necessary with further support for teachers and students and grade-appropriate readings. The intention is for the comparison curriculum to contrast with the treatment curriculum in pedagogical approach.

## Methodological Approach

Video data collection in each class includes all time spent on the engineering curriculum (treatment or comparison). Between one and three cameras are set up in each class. In all classrooms, one camera is trained

upon the teacher and a portion of the classroom containing only students with parental consent. Where another camera or cameras are available, each follows the same student group throughout data collection. At the end of implementation in each classroom, some students are asked to participate in focus groups, where they are interviewed on a number of topics, including their interest in engineering and self-concept as engineers.

Promising episodes from the videos showing student attitudes towards engineering are identified from observation notes and first-pass logging of all files. We look for cases where students talk about engineers or engineering, especially in a personal way, for example when a student says “I’m good at engineering”. For these episodes, we develop codes and explanatory theories by repeatedly comparing between theory and data in order to test and refine theory and increase explanatory power. We have collected qualitative measures of student engineering interest and self-concept, which we will compare to coded student work samples, and the student interest/attitude surveys collected from the video case study classrooms. Our goal is to begin to answer the questions, “Does the treatment foster more positive interest in and attitudes towards STEM careers?” “To what extent does the treatment affect students’ self-concept as engineers?” and “How do differences in treatment, as well as differences in fidelity and quality of implementation, moderate outcomes?”

## Preliminary Findings

Thus far, we have collected video from 15 classrooms, and are in the process of collecting from 9 more. We have noted episodes where students expressed positive or negative self-concepts in engineering. These tend to be associated with success or failure in meeting engineering design challenges. In our continuing work, we test these associations and look for mediating contexts and frames: for example, time available to improve designs and communicate with other teams about what they learned, or a focus on learning through overcoming failure. For final paper see: [http://eie.org/sites/default/files/research\\_article/research\\_file/icls\\_poster\\_proposal\\_2014.pdf](http://eie.org/sites/default/files/research_article/research_file/icls_poster_proposal_2014.pdf)

## Potential Significance and Relevance to ICLS 2014

This research addresses the theme “Learning and Becoming in Practice” by examining how students’ attitudes and self-concept in engineering change as they engage in different engineering curricula—one of which focuses on engaging students explicitly in developmentally appropriate disciplinary practices of engineering. The potential significance of this work is in developing a better understanding of the contexts and frames that affect students’ disciplinary identification and self-concept; also improving understanding of how educational learning environments can be influenced by elements of curriculum design and teacher training.

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# **Local Ground: A Toolkit Supporting Meta-representational Competence in Data Science**

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**Abstract:** Local Ground is an online data collection, mapping and visualization platform that allows youth to learn and use data skills in support of local projects. Local Ground is unique in its ability to display and translate between a variety of representations of spatial phenomena, starting with drawings. In our studies, we have found that students have used Local Ground to combine and translate between different representations for sense-making and communication.

## **Introduction**

The term data science has been coined to describe the mindset and skills one must possess to acquire, manipulate and use data to understand and predict real-world phenomena, and to communicate that understanding for decision-making. Data scientists play increasingly important roles in a variety of fields - including public health, climate science, governance, the social sciences and for study of the Internet and telecommunications networks. Researchers have observed that data scientists require a unique combination of skills - including statistical reasoning, information organization, and algorithmic thinking (Kandel, Paepcke, Hellerstein and Heer, 2012).

Local Ground is an online data collection, mapping and visualization platform that provides youth with an opportunity to learn and use data skills in support of local civic engagement and citizen science projects (van Wart, Tsai and Parikh, 2010). Local Ground allows learners to 1) collect locally relevant data, including as hand-drawn map annotations, unstructured audio and images and handwritten tables, 2) enter, tag and georeference this raw data into a usable digital format, 3) explore and visualize this data, including as heatmaps, tag clouds, graphs and charts and 4) create compelling narratives from data and multimedia, to be presented and shared with others. We have applied this process of data-driven inquiry across subjects and age groups, from elementary to high school, while working on projects of local civic significance - what Freire calls "generative themes" (Freire, 1970).

## **Meta-Representational Competence and Data Science**

Local Ground is a type of "auxiliary stimulus" - a cultural form that is wedged between students' naive ways of thinking about spatial phenomena and their spontaneous inclinations to represent this thinking. Local Ground is unique in its ability to display and translate between a variety of distinct representations of this phenomena, starting with and-drawing on existing maps. Drawing has been referred to as "probably the biggest and most obvious pool of competence" in children (diSessa, 2004, p. 309). Researchers have also observed that using drawing, students are able to reinvent a number of canonical representations, including graphs and maps (diSessa, Hammer, Sherin and Kolpakowski; Enyedy, 2005). Enyedy refers to this process as progressive symbolization, progressively refining representations of the world to develop a deeper (and more operational) understanding of a domain (Enyedy, 2005).

Data scientists must also create and translate between representational formats as they manage data across the pipeline - from collection, to entry, to modeling, to programming, and finally to communicating results (Kandel et al., 2012). They must integrate data and visualizations into compelling narratives, in the form of presentations, videos and graphics, that can influence decision-makers, the public and even themselves (Segel & Heer, 2010). Enyedy observed how students in a 2nd and 3rd grade class reinvented topographical lines as a solution to representing height in a 2D map (Enyedy, 2005). He describes "how the invention of representational forms by individuals occur as part of a larger social process of creating cultural conventions" (Enyedy, 2005, p. 427).

## **Case Studies**

### **Participating in Urban Planning**

Y-PLAN is a design studio based at the Center for Cities and Schools at UC Berkeley. Y-PLAN facilitated a partnership between Berkeley students (mentors), the City of Richmond, and an eleventh grade U.S. history class, to support youth involvement in creating a design plan for a local park. The students went through a twelve week design process, using Local Ground to collect data about existing assets, hazards and risks; created models, and used this information to advocate for a future neighborhood design plan.

## **Monitoring Air Quality**

EBAYS (East Bay Academy for Young Scientists) is a summer science program for low-income youth, sponsored by the Lawrence Hall of Sciences. Working with E-BAYS, students gathered, analyzed, visualized, and summarized air quality data using Local Ground and other tools, and presented their data and findings to their parents, community members, the Port of Oakland, the transit commission, and at the American Geophysical Union (AGU) conference.

## **Ground-Truthing Civic Data**

I-SEEED is a community organization supporting youth involvement in economic, environmental and educational design. Working with I-SEEED, a local school district and other community organizations, youth from different neighborhoods in Oakland used Local Ground to ground truth an existing “grocery store” dataset. Local Ground enabled young people to submit and geo-reference photos, audio clips, comments, and ratings of the stores they visited, and communicate to the school district that only about a third of the stores in the “grocery store” data set provided even moderately healthy food options.

## **Preliminary Findings and Future Work**

In all of these projects, we have found that students have leveraged different representations of data for sense-making, analysis and communication. In the case of EBAYS, when students presented their findings to parents and community members, they used a Local Ground map to represent the spatial coverage of their study; a time series plot to represent how air quality changed over the course of a train ride; a comparative chart series to represent the striking difference in Air Quality between the Pittsburg and Embarcadero stations, a photograph of the train station to demonstrate dust accumulation, and finally some summary statistics using tabular formats. In the Y-PLAN, when students presented their park design plan at City Hall, they used Local Ground as a way to show future visions of the neighborhood, juxtaposed with a photograph in which an existing methadone clinic was sited next to a proposed playground. These representations were later combined in a PowerPoint presentation that also included poetry, spoken word, graphic posters, etc. In the case of I-SEEED, youth used a combination of drawings, pictures and tables to collect data about grocery stores. Based on this data, mentors helped students to create a visualization that colored store locations based on their categories. Later, they made a multimedia presentation combining audio and images to communicate their qualitative findings.

We plan to conduct further studies of the use of representations to collect and understand empirical data. Working with students in grades 4-8 at two local schools, we will be observing how students appropriate the affordances of the tool to create new representations of space and spatial phenomena. We are also interested in how students convert these representations into more usable and communicable forms, how and if those forms are appropriated by others, and how that process supports youth’s understanding of core mathematical, statistical and computational constructs. We also want to understand the importance of locally collected data on youth motivation and identity.

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## **Acknowledgments**

We would like to thank I-SEEED, Lawrence Hall of Science, E-BAYS, Y-Plan, the UC Center for Cities and Schools, all of our other collaborators and especially all of the students that have participated in our work. This material is based in part upon work supported by the National Science Foundation under Grant Number IIS-1319849.

# Make to Relate: Narratives Of, and As, Community Practice

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**Abstract:** As young people design, build, and problem-solve within maker spaces and clubs, they talk about making. We analyze short interviews with youth makers, conducted during presentations of their products, and hypothesize a progression through frames of participation. Moving from *exploration*, to *exchange*, and on to *deliberate engagement*, these frames reflect changes in the nature of participation, appropriation of community practices and dispositions, and adoption of making as a tool for identity work and interest development.

## Learning in Making

Interest in making and the maker movement is on the rise, driven both by the increasing visibility of these activities in the public sphere, and a broader shift in educational research toward informal and interest-driven learning environments in STEM education (e.g., NRC, 2009). Efforts to graft the goals of STEM educators onto existing maker practices and communities must grapple with the values, identities, and “mindset” already associated with the maker movement. In particular, researchers and educators hoping to design for learning through making can benefit from greater understanding of how youth appropriate the dispositions, discourses, problem-solving approaches, technical knowledge base, and identity of the maker community (Herrenkohl & Mertl, 2011). Further, maker clubs’ encouragement of creativity and the open-ended nature of projects lend themselves to an inquiry into how and why youth re-craft their environments and what resources they draw from to do so (Bell, et al, 2013)

In this paper, we report on how young people’s ways of *doing* and *telling* reflect paths toward *knowing* and *being* as makers and learners. We analyze nine short interviews with youth makers conducted as they presented at Maker Faire, a large regional exposition. These interviews constitute narratives of practice, describing challenges, goals, and resources. They also represent a cultural activity central to the maker movement: sharing what you made. Given this dual lens, we treat these data as interpersonal narratives and focus on the narrow question: how do young people participate in and talk about the practice of exhibiting their work at the Maker Faire?

## Methods

As part of a larger study of young people participating in makers clubs, we interviewed eleven youth during, or shortly after, they presented a project at Maker Faire. Questions asked youth about their experiences as makers, allowing them to surface the most relevant experiences (Ching & Kafai, 2008). Three young women and eight young men, aged 11 to 15, participated. Following a grounded theory approach we made an initial pass through the transcribed interview data, during which we documented observations and potential codes. In subsequent passes we consolidated, refined, and illuminated our understanding of categories and patterns in the data.

## Framing Participation

In our analysis, we noticed that youth differed in the ways they exhibited their work, and in particular how they engaged with their audience. Mapping these differences onto the young people’s level of experience at Maker Faire (based on their reported number of times visiting and presenting), we constructed a progression of frames for participation in making (see Figure 1).

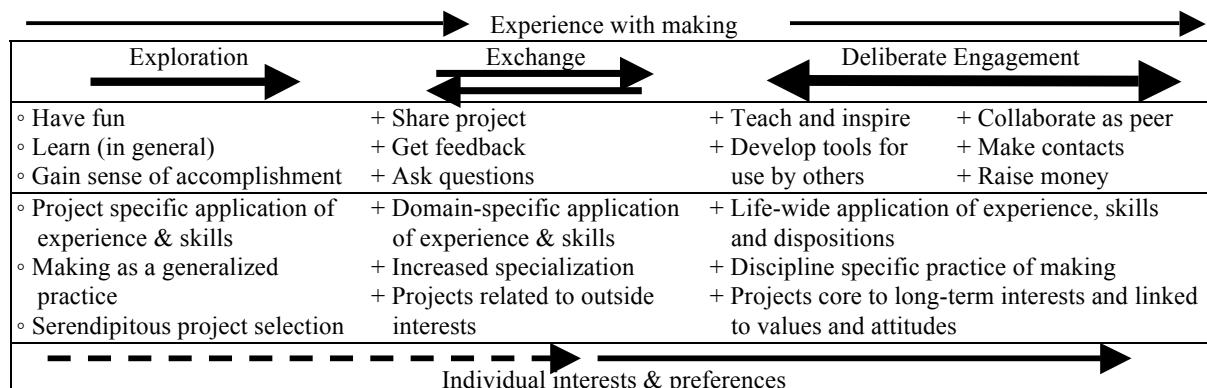


Figure 1. Hypothesized progression of frames for participation

Given the descriptive nature of our work, we see this as a *hypothesized* trajectory of participation, rather than a definitive learning sequence. Although we see these frames unfolding over time, we do not assume a linear, unidirectional trajectory, nor do we assume that these ways of participating and performing necessarily cross domains. Each frame represents a cluster of related elements.

With the space remaining, we provide illustrative examples of this progression, which moves from more egocentric frames for participation toward other-oriented and shared frames. Poster presentation of data will allow us to provide more complete portraits of the young people making, telling, and developing in this space.

On the left of Figure 1 is the *exploration* pattern. Asked what was valuable about being a part of Maker Faire, the least experienced makers emphasized the benefits of seeing and absorbing the experience: having fun, learning (generally, not a specific skill or topic), and gaining a sense of accomplishment. Asked what they would do next with what they learned in making, these young people talked about doing additional projects that were similar to their current work. They represented their project choices as somewhat serendipitous or trivial: they had happened to see an interesting project, or wanted to make something that was “loud and annoying.”

In the *exchange* pattern, youth with more Maker Faire experience connected their choices to longer term interests. In one maker’s words: “I was inspired – I’d already been working on it for a long time before I decided to bring it to Maker Faire.... mostly I wanted [my project] as toys, things I could actually use.” Two young women used their project to link a long-term focus of imaginative play to a current hobby. These makers emphasized the importance of showing people what you did, either to get feedback or to display particular traits or skills (e.g., “creativity” or coding). They valued their enjoyment of the process, but began including others – specific mentors as well as a broader public audience – more centrally in their narratives.

In the third pattern, *deliberate engagement*, youth not only placed others within their narratives, but began to consider specific roles or outcomes for these people. They linked development of skills within making activities to future work and enduring commitments. For example, the three most experienced makers discussed the role that Maker Faire played in developing resources – material, human, or emotional – to support long-term aspirations. They also tended to think of next steps in terms of building skills (e.g., coding, metalsmithing) to expand their potential as makers, rather than focusing on the next thing they could build. Most important, experienced presenters wanted to prompt action or create experiences for others. Examples ranged from enlisting knowledgeable partners and financial supporters, to creating tools or instruction that others can use, to inspiring others and “show[ing] other kids that they can make things too and they don’t have to wait until they’re older.” (Jaimie, age 14)

## Conclusion

Though drawn from a small sample, the hypothesized trajectory of participation we describe illustrates an important aspect of what it means to become a maker and a fuller participant in the maker movement. As we continue to analyze in-depth case studies of maker clubs, we will be able to refine this hypothesis to better understand the relationship of these narratives to participation in other making activities. The narratives likely reflect both variation in observable experience and in appropriation of the discourse and ideologies of the maker movement.

Understanding the ways in which youth position themselves through narratives and performance in making, and how these align with positions and practices of the larger maker community has implications for research and design. Shifts in how young people and the adults around them frame their participation are integral to learning processes and outcomes. Connecting with the conference theme, *becoming* a maker is integrally tied up with how participation is *framed in practice*. This analysis shows that young people understand their participation not only in terms of interaction with technologies and materials, but also with friends, mentors, and a larger community of makers (and potential makers). With extended participation, they may be using making to strengthen and expand identities and relationships, along with maker-specific skills of crafting and coding.

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# **Gesture Enhancement of a Virtual Tutor via Investigating Human Tutor Discursive Strategies: Forms and Functions for Proportions**

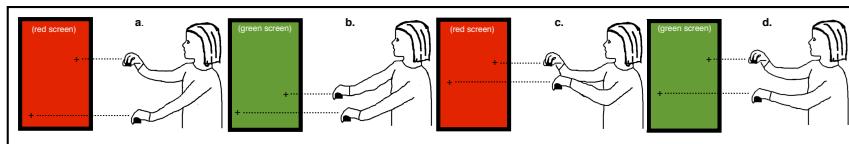
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**Abstract:** We examine expert *human* mathematics-tutor gestures in the context of an interactive design for proportionality in order to design a *virtual* pedagogical agent. Early results implicate distinct gesture morphologies serving consistent contextual functionalities in guiding learners towards quantitative descriptions of proportional relations.

## **Towards a Virtual Pedagogical Agent Capable of Instructional Math Gesture**

Mathematics teachers spontaneously employ gesture as spatio-dynamic complements to verbal and symbolic utterance (Alibali et al., 2014), and a growing body of work emphasizes such multimodality as an essential dimension of instructional practice (e.g., Arzarello et al., 2009). However, to date, virtual pedagogical agents (VPAs) embedded in teacher-independent mathematics tutorials *lack instructional gesturing capacity*. Our NSF-funded CyberLearning EXP design-research project seeks to integrate an animated, gesturing VPA with The Mathematical Imagery Trainer for Proportion (MIT-P), an embodied-learning device (Abrahamson et al., 2012).

The MIT-P was designed to provide an interactive context for students to ground proportionality in sensorimotor schemes. Students first discover an operatory scheme for achieving a non-symbolical goal state of a technological device—in Figure 1 this state is “green”—and then signify their strategy mathematically. The human tutor guides learners through the discovery of green-making hand movements and then facilitates a sequence of shifts in their green-making strategies toward a mathematical register. Each of these shifts is onset, formed, and enabled by a new symbolic artifact the tutor introduces onto the screen (cursors, a grid, numerals).



**Figure 1.** When the Mathematical Imagery Trainer for Proportion (MIT-P) is set to a 1:2 ratio, the right hand needs to be twice as high as the left hand in order to make the screen green. Learners receive green feedback when hand heights embody a 1:2 ratio (b, d) and red feedback when hand heights depart from this ratio (a, c).

## **The Construction of a Classification Scheme of Human Tutor Gesture**

To design the VPA, we are collaborating with animation specialists from the UC Davis Motion Lab who will create a virtual, gesturing character according to our pedagogical specifications. Because the VPA will be limited to a finite repertoire of gestures and vocalizations, our early task is to schematize the most consequential multimodal tactics human tutors employ in the MIT-P context for the animation team to render. Towards this goal, we are examining form (“what”) and function (“for what”) of human tutor gestures in our corpus of 23 intensive video-recorded task-based interviews with Grade 4-6 students. The need to parameterize gestures *for simulation* has necessitated that we develop new methods for accurately and systematically articulating expert tutor gesture. To this end, our analysis of human tutor gestures attends to: (1) their occurrence in the temporal context within the tutorial sequence; (2) their spatio-dynamic morphology (e.g., hand shapes); (3) their coupling with focal artifacts (e.g., computer monitor); and (4) their service as a MIT-P tutorial tactic (Abrahamson et al., 2012). We propose that items 2 and 3 describe gesture *form* while 1 and 4 are descriptors of its *function*. Below, we present cases that highlight gestural variation observed during three critical phases of the interviews.

## **Distinct Forms of Pedagogical Gestures Contribute to Common Functions**

As students embark on their initial explorations of the conditions that make the screen green, an early function of tutorial gesture is to encourage learners to explore novel spatial regions of the screen (Figure 2, A1-3). Later, a second function of tutor gesture is to highlight latent properties of the logico-quantitative relationship between the two cursor heights (Figure 2, B1-3). Still later, as students begin to describe the underlying interaction pattern quantitatively, tutor gestures become components of revoicing student strategies, such as in illustrating the iterative-additive and multiplicative relationships (Figure 2, C1-3). As illustrated in Figure 2, however, the forms of each of these instructional-gesture functions may be diverse in terms of spatio-dynamic morphology and coupling (or lack thereof) with environmental focal artifacts. Despite this diversity in gestural component,

each of the distinct forms bears its desired functional effect in prompting further exploration, eliciting preliminary relationship hypotheses, and supporting more detailed articulations of quantitative relationships.

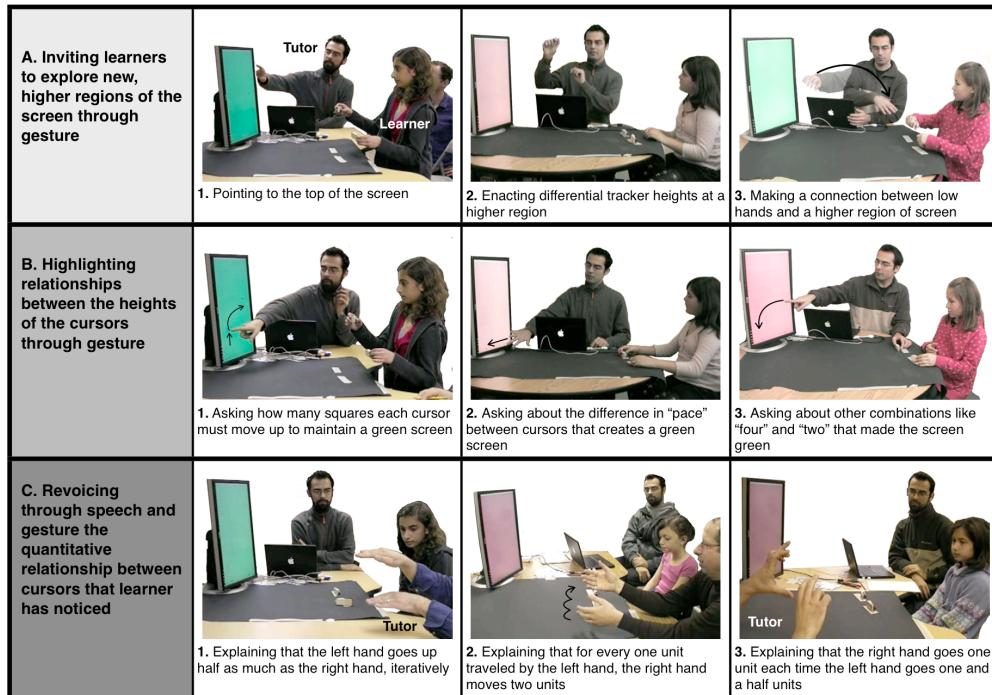


Figure 2. Three functions of MIT-P tutor gestures and their distinct forms.

## Conclusions, Implications, and Benefits of Design Work

A serendipitous benefit of taxonomizing naturalistic gesture for the purpose of designing virtual gesture may be, reflexively, to reveal and highlight potentially critical features of instructional gesture that have been previously inaccessible to coarser categorization schemes, such as variation in gestural forms. Past work on instructional gesture in math learning settings emphasizes the *similarity* of gestural forms serving similar broad functions (e.g., “linking episodes” in Alibali et al., 2014). However, we emphasize the nuanced *variety* of gestural forms used for the same highly specific functions. We submit that this variety promotes student understanding (e.g., by depicting different spatial metaphors for the same mathematical idea; see C2 and C3 in Figure 2).

Another benefit of our research has been the design and production of a novel technological system for the efficient capture and representation of dozens of morphologically unique semiotic bundles (Arzarello et al., 2009). Our solution was to create a comprehensive GIF-clip library (Figure 3) of human tutor pedagogical choreographies based on human reenactments of the authentic tutorial tactical moves. This technique allowed us to preserve and organize the many variable forms of gestures by function for their future simulation.

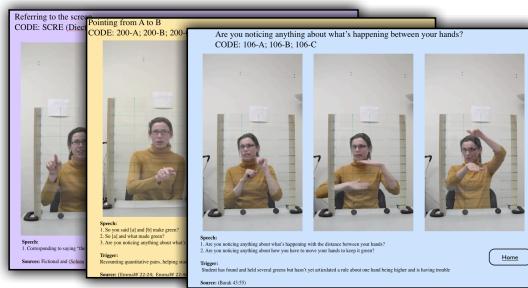


Figure 3. Selections of GIF-clip library of re-enacted pedagogical gestures for mathematics

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# Beyond ‘Solve for x’: Integrating Equations with Conceptual Understanding

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**Abstract:** This research attempts to describe how biology students’ integrate equations with disciplinary concepts. First, I assess how students’ explanations of biological phenomena change after solving word problems and receiving feedback from a quantitative simulation. Then, I describe a novel learning environment for further exploring design principles that support students in integrating equations with conceptual knowledge. With biology careers increasingly demanding mathematical approaches, students are better prepared to enter these careers if they can integrate equations with conceptual knowledge.

## Introduction

Historically, scientists have touted mathematics as *the language of nature*. Modern Learning Sciences perspectives adopt a less romantic approach by arguing that mathematics supports communication (Lemke, 2003) and cognition (Schwartz & Moore, 1998). Science students who receive instruction with mathematics, however, often fail to integrate equations and algorithms with conceptual knowledge. The present research aims to assess how science students’ explanations of phenomena change after solving word problems and receiving feedback from a quantitative simulation. The research further aims to identify design principles that support learning with mathematics in science. Integrating mathematical representation and procedure with conceptual knowledge better prepares students for research careers and collaborations across STEM disciplines.

## Equations in Science Education

Regarding instruction, physics and chemistry educators traditionally teach science with equations and assess students’ understandings by posing word problems. Educational research in these disciplines demonstrates that students struggle to integrate equations and algorithms with conceptual understandings of science content (e.g. Nakhleh, 1993). When educators attempt to relieve difficulty, improve performance, or teach non-science majors, they often shift to a conceptual approach that eliminates equations from instruction. Treating mathematical and conceptual approaches as separate, however, reflects a false dichotomy. The present research aims to improve our knowledge of how students integrate equations with disciplinary concepts when learning with technologies designed to foster integration.

## The Knowledge in Pieces Approach

The KiP framework offers a systematic approach to analyzing how students’ organize *knowledge elements* vis-à-vis equations. KiP refers to the fragmented bits of knowledge that students coordinate to complete disciplinary tasks (diSessa, 1993). The KiP approach maintains that students’ knowledge elements exists as a *system* that resides in a state of flux as opposed to a coherent structure organized around stable theories and beliefs.

The KiP framework was applied previously to characterize how students understand physics equations (Sherin, 2001). By Sherin’s analysis, students understand physics equations by using the knowledge elements *symbolic forms*. All forms consist of a *symbolic template* and a *conceptual schema*. The template denotes the abstract structure that students recognize in an equation and the schema denotes the general idea that the template represents. Students interpret equations by recognizing their abstract structure. For instance, upon recognizing a term as a coefficient, students explain that the coefficient “just tunes” the size of an effect. The present research aims to (1) explore the generativity of Sherin’s framework by extending it from physics to biology education and (2) identify domain-specific design principles that support biology students in integrating equations with conceptual knowledge.

## Methods

Students ( $n = 10$ ;  $M = 20$  years;  $Range = 20\text{-}23$ ) were concurrently enrolled in a (200-level) biology course titled *Homeostasis*. Students participated in semi-structured interviews that asked them to answer the question, “How does a cell *generate* a resting membrane potential?” Then, students were randomly assigned to either solve word problems with a quantitative simulation that mathematically models how cells generate resting membrane potentials or, for comparison, to observe a narrated animation that explained this process. After receiving instruction, students answered the question once more. Students’ explanations were video and audio recorded for later transcription and analysis. Data were collected in a laboratory setting.

Regarding the domain under consideration, biological cells possess the capacity to generate transmembrane voltages. If an ionic species is more concentrated in the intracellular fluid than in the extracellular fluid, then the species will tend to diffuse down the chemical gradient due to random motions. Because cells

possess ion-selective protein channels, some ions will diffuse down their gradient, carrying their charge with them. This causes oppositely charged particles to separate at the membrane. The value at which the electrical driving forces balance the chemical driving forces is the cell's resting membrane potential or steady state voltage. We can model this system mathematically with the Nernst and Goldman equations (see Equation 1).

$$(1) E_x = 60 \cdot \log \frac{[X]_o}{[X]_i} \quad (2) V_m = \frac{G_x}{G_T} \cdot E_x + \frac{G_y}{G_T} \cdot E_y + \frac{G_z}{G_T} \cdot E_z \dots$$

Equation 1. (1) Nernst potential. (2) Goldman equation transformed into the Nernst potential ran in series.  
Coefficients denote the relative conductance for each ionic species.

Using techniques borrowed from diSessa (1993) and Sherin (2001), students' linguistic descriptions were analyzed and categorized according to knowledge elements.

## Results

Preliminary analysis suggests that students rely upon the symbolic form cluster *competing terms*. Competition refers to two or more influences that vie in a struggle to produce some final effect. Within this cluster, students draw heavily upon the symbolic form *balance*. Sherin (2001) describes *balance* as "two influences, each associated with a side of the equation, in balance so that the system is in equilibrium" (pg. 533). Similarly, diSessa's (1993) describes the knowledge element *dynamic balance* as "a pair of forces or directed influences that are in conflict and happen to balance each other" (pg. 222). For instance, one student stated, "So there has to be an equal amount of charge, not an equal amount of charge but it's kind of like two opposing forces. Like the concentration and also the charge."

Whereas instruction with a quantitative simulation promoted students to shift to cuing the *equilibrium* (stability within parameters) and *equilibration* (return to stability) knowledge elements, instruction with a narrated animation promoted students to shift to the *balance* element. For instance, after solving word problems with the simulation, one student stated, "When things get out of whack [...] the cell wants to get things back to its composition of the way that it works most efficiently. So it's going to either take the ions out of the cell or take the ions from the outside of the cell and bring them in to reach equilibrium." Thus, she cues the *equilibration* element. In contrast, a student who experienced the animation stated, "There comes a point where they reach a balance, where the diffusion force will equal the electric force." Thus, he cues the *balance* element.

## Conclusions and Future Directions

The KiP framework holds promise for knowledge analysis in biology. The initial phase of the investigation suggests that learning with equations *can* shift the cuing priority of knowledge elements differently than learning without equations. Unfortunately, these results suggest that learning with equations in the absence of explicit instructional support fails to shift students towards productive mechanistic reasoning compared to learning with a narrated animation. This marks the first step towards the next phase of the investigation where the goal will be to design a learning environment that helps students better integrate equations with disciplinary concepts. Specifically, the design will aim to leverage the affordances of both the quantitative simulation and the narrated animation. The potential design solution aims to foster reflection and the integration of knowledge by providing students the opportunity to relate the two instructional media to each other and to their own understanding. The design aims to accomplish these ends by promoting students to generate representations of their knowledge while learning with equations.

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## Acknowledgments

I would like to thank Mike Stieff for his many helpful comments on the ideas presented here.

# Purposeful Learning across Collaborative Educational Spaces

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**Abstract:** This paper presents the overall goals and preliminary results of an on-going research project that aims at: understanding the intricacies and complexities of introducing mobile technologies into schools' curriculum and accepted teaching practices; analyzing actual transformations that the use of mobile technologies in schools brings to contemporary forms of learning. The results of the project will contribute to a better understanding of new media literacies and their implications for curriculum design and everyday educational practices.

## Introduction

Digital competence and social networking practices are today seen central for citizens of the 21st century (Lucas and Moreira, 2009). However, recent studies have shown that most of the innovations related to the use of ICT in schools have not impacted pedagogical or school development (Buckingham & Willett, 2006; Coiro et al., 2008; Snyder et al., 2010). The problem is far from being trivial since online communication and interaction are not longer a separate phenomenon from children's daily lives. In this socio-technical reality, schools, in particular, are deeply challenged as they are confronted with questions such as: What kinds of strategies, skills and competencies are learners developing outside schools? What are they learning in their interaction with digital tools? Which opportunities for learning and work do digital tools really afford? How are schools aligned to the conditions for learning and teaching that the use of digital tools promotes today? Goodyear (2011) claims that we are facing two perceptible changes in the field of educational research. The first is a shift in our sense of the spaces and contexts in which education takes place, as different learning activities are becoming more commonly distributed across a variety of contexts. The second change is a wider understanding with regards to the conception of educational praxis, acknowledging the growing importance of design. In order to better understand some of these emerging challenges, we have recently started a 3 years research project aiming at: i-understanding the intricacies and complexities of introducing mobile technologies into schools' curriculum and accepted teaching practices and ii-analyzing the actual transformations that the use of mobile technologies in school bring to current and future school practices. In order to address these research challenges, we have decided to focus on two distinct but complementary domains as starting points for our investigation: the teaching of mathematics and Swedish as a second language.

## Research Questions

- Why and how do schools introduce mobile devices into mathematics and language learning everyday classroom practices? And which pedagogical standpoints should be considered in such endeavor?
- How does the use of mobile devices transform classrooms' practices and, in particular, learners' understanding of mathematical and linguistic concepts? And how are mobile devices adopted and shaped by teachers and learners' practices in mathematics and language learning classrooms?

## Methodology

The research project consists of three main phases: i-examining teachers' ideas and prejudices about using mobile devices in the classroom; ii- preparing the introduction of mobile devices into the classrooms of mathematics and language domains; iii- studying the transformations that the introduction of mobile devices bring to the classrooms' talk structure and examine what kinds of instruments teachers and learners can create from mobile devices introduced into the learning of narrative genre and basic geometrical concepts. The project is grounded in design-based research (DBR) research methods (Brown, 1992; Hoadley, 2004, Mor & Winters, 2007), and it thus blends empirical education research with theory-driven design of learning environments. For studying types of transformations the use of mobile devices brings to the classroom, we have chosen to focus on the analysis of verbal interactions (Kerbrat-Orecchioni, 1990; Pachler et al., 2010) and on the outcomes produced by the learners such as multimodal texts, diagrams, graphs, films, interactive presentations, experiments etc. from the perspective on multimodality developed by Kress (2010).

## Ongoing Data Collection

We have so far conducted 20 interviews with K-12 teachers working in four different schools located in Sweden. Three of the schools have already implemented the use of tablets (Ipads) in their classroom and one of

them is considering starting using tablets in their teaching. So far, teachers of Swedish as a second language, who daily use tablets for teaching purposes, mentioned children use these devices for expressing themselves as they can easier communicate their ideas through films, presentations, and drawings. They make use of applications such as Dragon speech recognition software that convert voice into text helping them to visualize how they and others talk and thus use spellings and grammar in their conversations. Audio books are also an application that students having Swedish as a second language appreciate, as they can read texts while being introduced to the prosody of the Swedish language. We think in some ways, Ipads are supporting affordances of visuals for communication that help children to both learning about the target language and to express themselves using different communication channels (cf. visual, auditive, pictorial). In teaching mathematics, teachers consider children's use of applications including graphs, pictures, images or films, as tools that scaffold children's understanding of abstracts concepts.

## **Next Steps**

The next steps of the project involve two distinct phases: 1-exploration of the design space and 2-study of transformations reflected in the classrooms' interactions and students' outcomes. In phase 1, we will continue conducting interviews and future workshops with teachers. The aim with the interviews and workshops is to identify: a) current problems in the teaching of mathematics and language concepts of narrative genre and basic geometrical concepts; b) teachers' views on mobile devices being used in the classroom; c) advantages and disadvantages related to learners' use of mobile devices in schools. At the end of this phase we will have a clearer picture of potential scenarios and supporting digital tools along with concrete pedagogical models. This should allow us to make concrete design proposals to the teachers and scaffold the development of phase two. In phase 2, we will direct our efforts toward the study of the transformations that the use of tablets or other type of mobile device bring to the classrooms' interaction structure and we will examine what kinds of instruments mobile devices actually become in teachers and learners' hands. During this phase we will also, together with the teachers, construct design and pedagogical interventions aimed to explore social, pragmatic, epistemic and reflexive transformations in classrooms (Cerratto-Pargman, 2006).

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## **Acknowledgments**

We would like to thank the Swedish Research Council for funding the PLACES project.

# Taking a New Perspective on Spatial Representations in STEM

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**Abstract:** Representational competence is a vital capacity in STEM disciplines and students must form strong representational expertise. When translating between highly spatial representations, students can successfully rely on external resources to simplify the process; however, this may come at the expense of producing durable mental representations. Here we introduce a software interface to help chemistry students perform spatially demanding diagram translations. We implicate *embodied perspectives* for addressing the production of such mental representations.

## Introduction

Scientists rely on the ability to make fluid translations between external representations within their domain (Kozma, Chin, Russell, & Marx, 2000; Kozma & Russell, 1997). Representational translations are particularly important in the domain of chemistry where students must learn to coordinate molecular diagrams, spectra, formulae, and concrete models to each other as well as to the phenomena they represent. In this discipline, the vast scale that separates the observable world from the represented world uniquely complicates translating among representations and presents a barrier to successful problem solving and conceptual change. As such, improving the ability to move fluently between representations, or *representational competence* (Kozma & Russell), is a central target for instruction and the design of new learning environments in chemistry.

Developing representational competence becomes increasingly important as students progress through the chemistry curriculum. In particular, college level instruction in chemistry emphasizes a highly spatial subset skill of representational competence: performing *representation translation* between standard molecular diagrams. Representation translation between molecular diagrams (hereafter RT) like the Fischer, Dash-Wedge, and Newman projections (see Figure 1) is a difficult task, as students must identify and transform a molecule's 3D spatial relationships through both holistic and internal degrees of freedom. Recently, empirical work has shown that RT can be supported through the use of concrete molecular models (Padalkar & Hegarty, 2012; Stull, Hegarty, Dixon, & Stieff, 2012). However, the utility of concrete models is tempered by reports that students find these models confusing and are unable to use them to solve RT tasks without significant guidance (Stull et al., 2012).

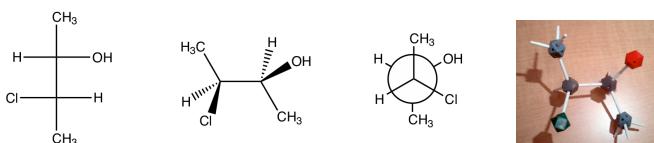


Figure 1. Equivalent representations of (2S,3S)-2-chloro-3-butanol: Fisher projection, Dash-Wedge projection, Newman projection, and concrete model (from left to right).

Stull, Barrett, and Hegarty (2012) have reported that externalizing RT tasks onto virtual molecular models provides students the same benefits found in studies of concrete models for offloading spatial relationships from working memory. Interestingly, Stull and colleagues have also found that students using virtual molecular models were more efficient in answering diagram translation questions and required little to no prior knowledge of chemistry. There is evidence, though, that when students are assessed in absence of such tools, performance on RT suffers (Stieff, Lira, Scopelitis, in preparation). This raises important questions about how students might most productively interact with highly spatial domain content and instructional scaffolds to produce durable mental representations for STEM.

We propose that such durable mental representations may be produced by enlisting the body to perceive structure through *embodied perspectives*. An embodied perspective is the physical alignment of the body in a perspective taking (PT) position relative to a spatial diagram and/or scaffolding representation (e.g., virtual molecular model). Evidence supporting this notion comes from multiple research traditions. Factor analytic work in spatial cognition has found that spatial visualization (mental rotation) and spatial orientation (perspective taking) are correlated but distinct cognitive processes (Hegarty & Waller, 2004). Thus, learning environments enabling PT should still support students with strong mental rotation abilities, but would provide students with weak aptitude for object-based transformations an alternative when working with highly spatial content.

PT construed solely as a mental operation, though, is cognitively expensive and may induce strategy switching (Kozhevnikov & Hegarty, 2001). However, if PT is repositioned as an embodied process, the act of

using the body to physically perceive molecular structure becomes a demonstrable process in teaching and learning settings (Scopelitis & Stieff, under review) and may also lead students to produce body-based schema (Wilson, 2002) that encode correspondence between perspective, structure, and structural diagrams. Such schema may then be recalled “off-line” (Wilson, p. 633) to catalyze thinking on similar and novel spatial tasks.

## A Software Solution and Further Implications

From known affordances of virtual molecular models and the proposed benefits of embodied perspectives, we introduce a software application that employs head tracking to allow students to embody multiple perspectives on chemical structures. A computer’s integrated webcam captures a student’s position relative to the screen and transforms it into reciprocated rotations. The virtual molecular model is then exchanged with its diagrammatic equivalent when a student’s position aligns with the view encoded in standard structural diagrams (see Figure 2). Additionally, students have immediate access to molecular structure through pre-selected examples and a search field that queries structure data from the National Institutes of Health (NIH) database. Students can enable standard molecular representations (depicted in Figure 1) after centering the molecule along “eligible bonds.”



**Figure 2.** Example of an embodied perspective with the molecule centered along an eligible bond. Students see how a ball and stick representation is exchanged for the appropriate diagram at relevant viewing angles.

We assert that the implications of this software reach beyond the chemistry classroom. The affordance of software learning environments to fluidly exchange representations may be beneficial in building students’ understanding of space-diagram correspondence. More significantly, embodied perspectives may serve as a general, instructable process for highly spatial content in any STEM discipline, producing stable mental representations for productive inferential reasoning and problem solving.

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## Acknowledgments

The research reported here was supported by a grant from the National Science Foundation (RESE 1102349). The opinions expressed are those of the authors and do not represent the views of these agencies.

# The Power of Networks as an Engineering Sophomore

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**Abstract:** Sophomore year for engineering undergraduates is competitive, high-stakes, and where many students choose to leave engineering for alternate majors. Through the lens of Actor-Network Theory, this paper explains the existence and significance of networks of power within the engineering sophomore class as observed ethnographically, with specific attention to the implications of power differentials for engineering persistence and retention.

## Overview

The 4-year engineering undergraduate curriculum is characterized by a rigid sequence of technical courses. Applied math and physics courses taken during the 1<sup>st</sup> and 2<sup>nd</sup> years are prerequisite requirements for subsequent technical engineering courses necessary for specialized engineering majors. Students who have difficulty with or fail a fundamental class during their first two years can seriously delay their graduation date or be discouraged from finishing the degree. Such experiences are known to discourage students and have been correlated with early departure from engineering majors (e.g., Seymour & Hewitt, 1997). Nationally, 82% of engineering students return for the second year, while only about 65% continue into the third year; there is a much smaller attrition rate between the third and fourth years (Fortenberry, Sullivan, Jordan, & Knight, 2007).

Engineering educators have focused on curricular interventions to improve the first-year experience (e.g., Sheppard & Jenison, 2007). However, little attention has been given to understanding the environmental or structural barriers that engineering students face during the second year of their education. The courses of the sophomore year mark the descent into “the valley of despair” as students are confronted with a seemingly endless march of technical requirements chained together with little wiggle room for electives or failure (Kotys-Schwartz, Knight, & Pawlas, 2010). The second year features gateway courses that eventually lead to the practice of engineering, courses that initiate students into greater levels of abstraction and analytical engineering problem solving. At the large public university we studied, the traditional engineering math sequence is Calculus 1 and Calculus 2 in the first year, Calculus 3 and Differential Equations in the second year. As our focal instructor told students on the first day of class in Calculus 3:

[This class is] somewhere between Calc 1, where everything is perfectly defined, and the 4-year end where nothing is defined and you don't know all the answers... it [uncertainty] has to start somewhere and that is *here* [emphasis added].

Within this challenging and uncertain environment, students must develop methods to survive the competition, including forming alliances and participating in networks like study groups, fraternities, and extracurricular programs. Students who successfully navigate the sophomore engineering terrain gain power in the form of higher grades, greater confidence in their abilities, and privileged access to material and human resources.

## Theoretical Orientation

Actor-Network Theory or ANT (Nespor, 2007) provides one means of examining the processes wherein students act in networks that place them on distinct educational trajectories in space and time. Network resources, including fraternity exam archives, residential engineering honors programs, and tutoring programs, all operate in distinct space-time locations with restricted access. ANT describes learning as changes in the organization (both temporal and spatial) of actors and networks, thus this theory offers a useful framework for studying the organization of students and emergent power dynamics within the competitive environment of the second year of engineering school. In line with ANT, we seek to uncover and describe the “ongoing social activities” that shape actor-networks and learning among students (Nespor, p. 12).

Using Actor-Network Theory, this study adopts an ethnographic approach in examining local classroom contexts and associated course activities to understand how sophomore student participation in university practices of engineering leads to power differentials. Differences in power among students can result in differential access to actor-network resources and impact important educational outcomes such as retention.

## Methodology

We observe two Calculus 3 classrooms: one, a large lecture-style with over 130 students, the second a smaller honors section of only 30 students, both taught by the same Instructor of the Applied Math department at our study site, a large public university. By first observing standard classroom practice, student actors and networks

of interest were identified for further detailed study through in-person open-ended interviews. Observational fieldnotes provided the backbone, primary record of events to be analyzed by the qualitative research team. Passages of interest were flagged, subsequently coded, and used for initial reconstructive analysis (Carspecken, 1996). Course artifacts including the syllabus, textbook, homework, exams, and projects, were collected to further inform the network analysis, though were secondary to our main focus on human actors.

Reconstructive analyses were compared and coded with the observations, artifacts, and interviews to reveal network connections as perceived by the students and as performed publicly during class. Salient student groupings, as discussed below, were identified through initial coding of observational, interview, and reconstructive data.

## Preliminary Findings

Preliminary analysis of the data indicates several emergent trends. First, in both classes, the Instructor is a major power player who guides the organization of the classroom culture, maintaining the framework within which students establish their own power hierarchies and actor-networks. The Instructor appears to be in charge, not only governing grades, homework assignments, projects, and exams, but also controlling how lecture periods flow, which students get their questions answered and which students get special attention.

The students, meanwhile, group themselves according to different strategies they use to negotiate the pre-established power hierarchy (the curriculum and supporting infrastructures). This includes those who follow stereotypical practices of good students like getting to class early and sitting in the front rows, as well as students who choose unorthodox strategies like playing games on their phones and ignoring most lectures. These student groups, or actor-networks, have distinctive characteristics, working styles, and methods of positioning themselves within the power hierarchy of the classroom. They not only have different positions within the power hierarchy, but they also have different levels of access to resources including Instructor help, previous exams, senior students to help with homework, and more. This power hierarchy is based on both valid and non-valid indicators of academic power, as some students incorrectly prioritize the ability to write code in Mathematica (a computer program) above conceptual understanding and communication of mathematical concepts, while other students eagerly share their test scores with their peers and know exactly where they stand with regard to the class's normal distribution and bell curve.

## Conclusions and Significance

Understanding how sophomore students organize themselves within actor-networks of power is essential for understanding how to support students within the competitive environment of engineering. Feeling empowered or disempowered within one's educational context affects not only student performance but also how much one feels like one belongs and desires to remain in that context (Marra, Rodgers, Shen, & Bogue, 2012). This study takes a new and novel look at what is happening in the second year of engineering school by analyzing the social currents of the process of becoming an engineer. This study breaks from traditional engineering education research by incorporating methods from the learning sciences and observing the development of student culture ethnographically (Johri & Olds, 2011). Because engineering education occurs within the larger context of societal power differentials, it is necessary to study and understand these processes in order to give more engineering students better chances at success.

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# Getting your Drift: Activity Designs for Grappling with Evolution

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**Abstract:** This poster presents the design of activities for engaging with the evolutionary mechanism known as *genetic drift*. Operating in the informal learning setting of a natural history museum, our design builds upon the theoretical notion of *embodied modeling* in an agent-based tradition, extending this foundation to address the special challenges associated with genetic drift and to take advantage of the affordances of immersive multi-touch technologies and of the museum setting.

## Introduction

This poster presents the design of an activity for learners to engage with the phenomenon of *genetic drift*. Genetic drift is a key mechanism of evolution involving traits that convey no survival advantage to organisms. The passage of such a trait to future generations is determined purely by chance and the distribution of variations in the population. However, against the intuitions of many, the feedback loop of this purely-probabilistic selection process over time creates a population that is completely homogenous with respect to the trait. Our design challenge is to develop activities that foreground genetic drift and enable visitors to engage with this mechanism. This work is a part of a larger project to make key evolutionary mechanisms accessible in informal settings and has been pursued in the context of a museum of natural history in a large Midwestern city with visitor groups often consisting of families, siblings, or close friends.

## Major Issues Addressed

As the noted geneticist Theodosius Dobzhansky (1973) famously wrote, “nothing in biology makes sense except in the light of evolution.” At the same time, nothing is more controversial in the American education landscape. According to recent surveys (Gallup, 2012), 46% of Americans do not believe in evolution, and a shockingly small number, only 15%, say they believe in naturalistic evolution. Thus, one key barrier to increasing understanding of evolutionary mechanisms in the general public involves simply engaging with the conversation in an open spirit of inquiry. Beyond the barrier of acceptance or belief, educators and psychologists have described a host of student misconceptions about evolution (e.g., Andrews et al, 2012; Catley et al, 2004; Sinatra et al, 2003; Wilensky & Novak, 2010). For the specific context of genetic drift, two of the most important of these misconceptions involve difficulties with conceiving of randomness as playing a positive role in producing emergent structure (Wilensky & Resnick, 1999) and challenges about conceptualizing the passage of “deep time” (Gee, 2000).

## Theoretical and Methodological Approaches

To address the challenge of supporting learners in reasoning about genetic drift, our activity design extends principles of *embodied modeling* (Wilensky & Reisman, 2006) within an agent-based approach (Epstein & Axtell, 1996) to biological systems. In agent-based modeling (ABM), elements of a system are represented by simulated computational entities whose interactions result in emergent whole-system behaviors. ABM offers many affordances for learning about complex systems, as it enables learners to tap into intuitions that they have about agent-agent interactions. In the context of genetic drift, however, it is not sufficient for learners to project themselves into the system as *agents*. In fact, the very premise of drift (i.e., that it involves traits that convey no advantage) suggests that the agent-perspective will be indifferent about those traits. Our extension to embodied modeling with ABM involves introducing *new perspectives* within a simulated biological system that permit learners to leverage practices of gaming to engage and reason about the phenomenon of drift in that system.

Designing interactive experiences for museums offers a host of additional challenges including software usability issues and creating a socially engaging experience for diverse visitor groups that unfolds in a very brief timespan. In our activity, visitor dyads are recruited to engage in “games about evolution” on a large multi-touch tabletop interface on the exhibit floor. Our initial game-scenario presents an ecosystem containing a population of lily-pad bugs that vary in the trait of body color (see Figure 1a), a trait which has no impact on the bugs’ chances of survival. Visitors are told that these bugs feed off of the algae that grows on the lily-pads, and that when they have eaten enough they reproduce asexually by dividing. Visitors can move the lily pads around in the pond at any time, simply by dragging them (Figures 1b and 1c) with their fingers. Their goal is to keep as many *varieties* of bugs alive as possible, for the duration of the game (600 ‘ticks,’ or about two minutes). Besides the pond-view itself, feedback on the bug population is given in numeric and graphical form.

After the pair has explored this first game, they are invited to play a second game. Here, the two members of group are asked to position themselves on opposite sides of the tabletop display. This time, their objective is to end the 600-tick game with a population that exhibits *exactly two* of the five body-color variations. After the games, participants are asked to individually reflect on the experience and articulate their reasoning and observations about what ideas they tried out and what happened to the bug populations.

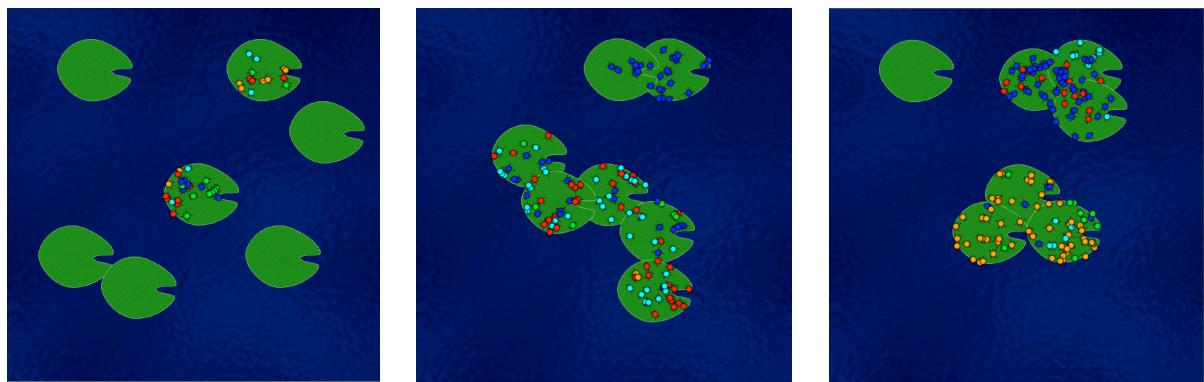


Figure 1a. Initial State of the game. Figures 1b and 1c. Configuring the pond.

## Discussion and Significance

In these activities, visitors engage with the bug population by controlling structural features of the environment. These interactions make salient the effects of key factors such as carrying capacity and geographical barriers on the growth patterns of the population, and in particular on the emergence of drift effects. In the first game, drift is figured as the antagonist or opponent, as participants work against it to preserve diversity. In the second game, visitors work in a contrary direction, using drift as a tool to select two particular trait variations for survival. In both games, visitors have a tactile means of constructing environments with the goal of resisting drift or harnessing it as a mechanism to create desired population-level outcomes. These interactions offer the means to grapple with the notion of random factors operating on traits in populations; to engage with a range of genetic drift effects within the brief timeframe that museum visitors typically spend with an exhibit; and to leave with a vivid experience that remains open for reflection and interpretation by the friends-and-family group.

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## Acknowledgments

Research presented in this poster is funded under NSF DRL-1109834, support we gratefully acknowledge. The views presented here are those of the authors and do not reflect positions of the National Science Foundation.

# Modeling the Dynamics of Ontological Reasoning in Physics

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**Abstract:** The form of learners' ontologies of physics concepts such as heat and electric current is a subject of current debate within the learning sciences. In one view, there is a cognitive barrier to transitioning between ontological categories; others argue that experts and novices transition flexibly between ontological categories. In this poster, we support the latter view through arguing that experts coordinate transitions between ontological categories for heat and electric current and discuss the instructional implications of these results.

## Introduction

The form of learners' science knowledge has been a topic of much debate within the learning sciences, hinging on the level of coherence and fragmentation the different perspectives attribute to naive science knowledge (diSessa, 2006). One prominent perspective is that developed by Chi (Chi, 2005), in which experts' and novices' reasoning about a science concept is constrained by their ontological commitments (commitments about whether the particular science concept can be categorized as *matter/substance* or a *process*). Once formed, these commitments are difficult to change except through conceptual change processes, leading to the robustness of ontological misconceptions (defined as mis-categorizations by novices). In this view, concepts such as heat, light, electric current are *emergent processes* and classified as such by experts. Novices tend to mis-categorize these concepts in the *substance/matter* or the *direct process* categories either due to a commitment to these categories, or due to a lack of the *emergent process* schema.

Recently, however, this view has been challenged, showing evidence that novices can and do reason across ontological categories (Gupta, Hammer, & Redish, 2010; Hammer, Gupta, & Redish, 2011) and that novices do not lack the emergent process schema (Levy & Wilensky, 2008). In this poster, we argue against the notion of ontological commitments: we present evidence that graduate students reasoning about heat often switch from speaking in terms of one ontology to another. We investigate the fine-timescale dynamics of such switching and posit that cues from the problem statement or interviewer, explanatory demands, learners' in-the-moment epistemological stances, and how they view the purpose of their explanation can contribute to the ontology underlying their reasoning as well as to transitioning to a different ontological description of heat.

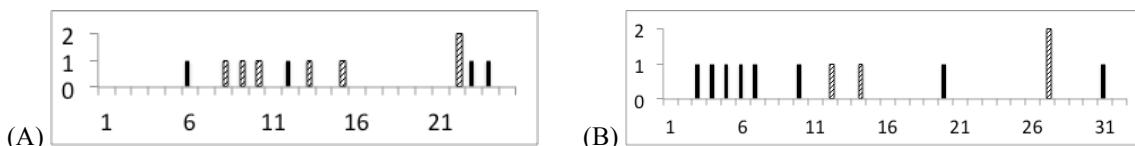
## Methods: Data Collection, Selection, and Analysis

The data comes from five one-hour videotaped interviews of physics graduate students from a previous project. The interview protocol followed Chi's and Slotta's tasks (Slotta, Chi, & Joram, 1995) to examine physics novices' and experts' ontologies of electric current, heat, and light. As part of the first author's high school magnet research internship, the heat and electric current sections of three of the interviews were selected for this analysis. Selection size was based on considerations of a high-school student research project.

The analysis occurred in two phases. First, transcripts of Sam's utterances in the selected portions were divided into 30 second segments and each segment was coded as reflecting *matter* or *emergent-process* ontologies using the predicate analysis method (Slotta & Chi, 2006). Instead of doing summary counts of predicate use for a topic, we plotted the predicate use *over time*. Second, we did a fine-grained analysis of the interviews, focusing more on segments where we noted category transitions (identified from the predicate plots). Loosely drawing on tools from knowledge analysis (Parnafes & diSessa, 2013) and discourse and framing analysis (Gee, 1999; Tannen, 1993), we aimed at a fine-timescale account of the transitions in the use of ontological categories, taking into account the content of talk as well as gestures, gaze, and tone of voice to infer the conceptual knowledge, epistemologies, and framings in use in the moment.

## Analysis

We present excerpts of our analysis of one of the interviews. Figure 1 shows the graph for Sam's (pseudonym) use of matter and emergent process predicates.



**Figure 1** Predicate use for Sam for the interview sections on (A) Electric Current and (B) Heat. 30-second interview segments are marked on the horizontal axis. Frequency of predicate use within a 30-second segment is marked on the vertical axis. Striped bars represent *emergent-process* predicates. Solid Bars represent *matter* predicates.

In this poster paper, we present the story of how one ontological transition plays out from the electric current section of the interview at the 22-nd segment. At this point, Sam was answering a question about two circuits each with one bulb attached to a battery, identical except that one has a longer wire and so the bulb is farther away from the battery. Sam stated that this is similar to an earlier question when she had to decide if “the current starts at the battery and has to travel to the light bulb.” However, she rejected that idea, saying instead, “The potential for current is everywhere in the wire at the same time (gestures in circular motion with arms to show the circuit). There are electrons scattered throughout that, or, not scattered. but spread throughout that wire, so as soon as one starts moving, they all move. So they are both gonna illuminate at exactly the same time.” Following this, the interviewer asked her which bulb is glowing more brightly. First, Sam posed the question “Are we assuming resistance-less wires?” to which the interviewer said, “You tell me why that would matter.” Sam explained how resistance affects brightness when the wires are different lengths because “resistance saps away” voltage as “current goes through the length of wire” and so “less voltage getting put into your light bulb.” Her gestures confirm that she is thinking of an entity physically moving through the wire.

Sam, contrary to the ontological framework of Chi and Slotta, showed no cognitive resistance to switching between *matter* and *emergent process* categories: in the first segment, talking about long and short wires, Sam’s explanation relies on an emergent-process understanding of current resulting from the simultaneous motion of electrons everywhere in the wires. Moments later, explaining resistance Sam’s speech and gestures reflect a *matter*-view of current flow in a circuit. Also, notable is Sam’s awareness, in each segment of the kinds of knowledge resources available to her and carefully chooses how to answer: she explicitly discusses the alternative way of reasoning and rejects in the earlier segment; later, even before answering she is aware that her answer would depend on whether wires have resistance or not and seeks to clarify that. Her responses here indicate some level of metacognitive awareness (what kind of knowledge is available to me) and epistemological evaluation (what kind of knowledge is relevant in this particular context).

## Summary and Implications

In this poster, we present our results (using fine-grained video analysis as well as verbal protocol analysis) that graduate students in physics can and do transition between ontological categories in their explanations of phenomenon related to heat and electric current. We show that such transitions are often influenced by the particular problem context (the specific phenomenon being explained within the larger category of heat and current) as well as metacognitive and epistemological evaluations. We argue that the target of ontological expertise should not be ontological conceptual change, where a concept is supposed to be re-categorized within its correct ontological category. Our results indicate that there might not be one “correct” ontological category (at least as reflected in experts’ behaviors); nor do we see a cognitive barrier to flexibly transitioning between categories. Rather, the target of ontological expertise might lie in an awareness of all the knowledge resources that could potentially be relevant to a particular situation and in developing metacognitive and epistemological resources to figure out what is the most productive way to reason in a given context.

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## Acknowledgments

We thank the interview volunteers. We thank Renee Michelle Goertzen for conducting the interviews.

# Finding Productivity in Design Task Tinkering

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**Abstract:** This poster looks at students' productive tinkering in a design activity. We analyze the emergence of a student-generated task and how the process of tinkering supported students in making progress in the task. In design activities, systematic, planned approaches are often valued over tinkering, a process which shortcuts that kind of analytical thinking. We argue that tinkering has value as a productive engineering practice and that it can support more systematic approaches.

## Introduction: Can Tinkering Be Sense-Making?

Tinkering is an ad-hoc approach to a problem and involves the practice of manipulating objects to characterize a particular system in an exploratory way, often with the goal of achieving practical success (e.g. Turkle & Papert, 1991; Berland et al., 2013). Tinkering contrasts more deliberate sense-making towards achieving conceptual understanding of *how* some phenomenon works. Some researchers see tinkering as unproductive because of the lack of clear aims, or because it does not prioritize conceptual learning (Law 1998; Yeshno & Ben-Ari, 2001). Others view it as productive for students' learning and for generation of novel solutions (Turkle & Papert, 1991; Berland et al., 2013; Roth, 1996). In this poster, we speak to this tension on the productivity of tinkering for novice designers and programmers. We claim that tinkering, or ad-hoc sense-making, can play a productive role in making progress towards design-activity goals.

## Method: Data Context, Selection, and Analysis

Our data comes from videotaped in-class group-work and interviews with a pair of high school students in a 2-week summer outreach program on physics. As part of the program, students learned to program Arduino (microcontroller) controlled robot-tanks (henceforth, Arduino-bot). The tanks could be programmed to move (via Arduino) and were fitted with basic distance and light sensors. Students spent the first week of the program working 1-2 hours per day on self-paced design tasks in pairs. The design task under consideration in this poster is one in which students had to program the Arduino-bot to make it turn if there was any obstacle in the tank's path (using the Arduino and the distance sensor for obstacle detection). Students were provided with a variety of resources, including sample code. The classroom was staffed by two instructors and several volunteers. Due to limited resources on the project, one pair was filmed each day, and two follow-up interviews were conducted. This analysis focuses on the fourth day of program, in which the two students, Hazel and Silver (pseudonyms), generated a task and attempted several strategies to solve it. We focus on this task because of the multiplicity of strategies employed and students' continued engagement in the task.

In this poster, we will present a fine-grained analysis of video data to characterize students' epistemic activities during the task. We look for evidence of particular student goals through speech, gestures and actions using interaction analysis (Jordan and Henderson, 1995). We also analyze students' talk as evidence of the knowledge students are drawing on (Parnafes & diSessa, 2013) and what they find productive. This analysis is intended to show that tinkering *can* be productive, and not necessarily that it is always productive.

## Preliminary Analysis: An Example of Productive Tinkering

Our focal episode begins when Hazel and Silver had just completed a task in which they were asked to make the Arduino-bot move forward until it detected an obstacle/wall, and then make a right turn. Hazel and Silver initially did not program the Arduino-bot to stop after turning right, so after the Arduino bot turns right it starts running over the keyboard until Silver grabs it. In response, they decide that they should make the robot stop after turning right. This goal of making the robot stop was not assigned in class, but many contextual events contributed to its reinforcement. First, we see the goal emerge through constraints of the physical space: had Silver not grabbed the bot, it would have run off the table. When Silver suggested modifying the task to stop the bot, Hazel quickly took up the task and offered suggestions of how to make it stop. This goal is reinforced by their interaction with other groups who sought input from Hazel and Silver on how to make it stop. The classroom culture of student ownership over the project task also played a role in their comfort in modifying the task statement - no group asked the teacher for permission to do this. In that sense, that the problem statement is emergent is some indication that students are in an exploratory mode in working with the robots. What follows in the next several minutes is Hazel and Silver tinkering through a variety of strategies to make the robot stop. We argue that such tinkering was productive for Hazel and Silver, and that it reflects authentic engineering practice.

In the first few minutes of trying to make the robot stop, the girls engage in the rapid testing of several

solutions to the problem. Here, tinkering supported extended engagement in the activity. They first try to change the digital settings of the motors, not knowing that the settings they were changing correspond to the motors' direction, not speed. This strategy leveraged knowledge that was productive in a previous task, in which rewriting a digital output from HIGH to LOW turned an LED off. We see this as tinkering because it does not attempt to draw out underlying principles of how the system works - they even verbally acknowledge that they do not understand what individual functions do. However, we see it as productive in that they notice the similarity between tasks (switching off motor versus LED) and draw on that prior experience. Next, the epistemic nature of their activity changes, as they try to make sense of how motor treads work (now extracting new information about the new system). Their dialogue and gestures give evidence that they see that turning a motor off will cause a corresponding tread to stop moving. After their first modification does not work, they spend a couple of minutes checking a reference guide and then search on Google for the solution, practices which were encouraged in class. We see this utilization of available resources, without getting too fixated on one resource, as productive trial-and-error. Later they isolate and execute individual lines of code (commenting out the other lines), to generate some knowledge about what individual commands do. These rapid trial-and-error activities occur in the span of about seven minutes.

One could argue that instead of tinkering Hazel and Silver should have systematically parsed the code to make sense of it; they would have had better task success and better learned Arduino programming through that. We contend this notion. Their activities reflect a recognition of the variety of resources at their disposal and a systematic walk through the resources to try and achieve their goal. They also reflect a certain level of judgment and resource management: they did not get fixated on any path, but quickly judged if the path would be productive, and if not, they switched tactic. These are all important skills in the design process, and within authentic engineering practice are not trumped by the value of systematic processing of the code.

We don't, however, deny that line-by-line processing of code is also a valuable epistemic practice. Indeed, when the other strategies don't make the bot stop in about seven minutes, Hazel and Silver begin synthesizing their observations into an understanding of what lines of code do. Hazel remarks, "So we know that, that HIGH was backwards." We then see Hazel parsing each line of the code in terms of its functionality, "So it takes a reading. It calls it for one second. It goes forward." However, it was while tinkering with the variables in the code that they explicitly problematized their lack of understand of certain functions. This awareness could have contributed to their getting to parsing the code to make sense of the functions. Tinkering can thus give students a sense for where they might focus a more deliberate analysis later.

## **Discussions and Implications**

Though tinkering may not lead to generalizable content learning, we argue that it has value as an engineering disciplinary practice. Tinkering produces useful knowledge for troubleshooting, and points out gaps in understanding, thus potentially prompting future systematic unpacking of ideas. Given the small sample size of present work, future work needs to be done to continue building on the productive role of tinkering in design activities. Work also needs to be done to understand how to encourage this kind of productive tinkering.

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## **Acknowledgements**

We thank Eric Kuo and Chandra Turpen for reviewing earlier drafts of the manuscript. We thank members of the UMD Physics Education Research Group for discussions.

# Making Mathematical Meaning through Robot Enactment of Mathematical Constructs

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**Abstract:** Learners of algebra struggle to understand the meaning of the symbolic and graphical representations they encounter. This paper explores the possibility of using robot enactment of mathematical constructs as a surrogate to support mathematical meaning making. We describe the Number Line activity design in a classroom network of handheld devices informed by the results of a pilot study indicating that students connected mathematical values to robot position and the sign of a value to robot motion.

## Mathematical Meaning and Physical Enactment

Making the transition from arithmetic to algebra presents learners with complex cognitive challenges (Herscovics & Linchevski, 1994). The same mathematical construct can have many different meanings and representations that must be connected and coordinated. Studies have explored the use of computer simulations and collaborative network technology to support learning necessary for algebra success (Hegedus & Roschelle, 2013). Nemirovsky, Tierney & Wright (1998) explored graphing supported by enacted physical phenomena.

The paper presents an initial exploration of robot motion as a surrogate (Fadro, Hallman Jr, Harris, & Black, 2009) to enact and model mathematical objects through positioning and movement in relation to a Cartesian coordinate plane or number line. We present the results of an initial pilot study in which students input values into a command line interface on a laptop computer to move a group of robots to points on a coordinate plane that define the graph of a quadratic function. We describe how these results inform the design of the Number Line collaborative learning activity environment developed for a classroom network of iPod Touch handheld devices connected to a robot server. The preliminary results of this ongoing study are reported in the proposed poster.

## Pilot Study Methods

The pilot study took place in two diverse K-8 schools, involving 132 seventh and eighth grade students in 5 algebra classes taught by two teachers. One wide-angle camera and 1 or 2 focus group cameras were used to capture video and audio for all sessions. Two researchers recorded field notes of the sessions. The two teachers and the research team jointly developed the technology supported classroom activities.

The goal of the activity was to enact a model of a quadratic function using robot position and motion. The x and y axes of two Cartesian coordinate planes with one foot units were taped to the floor. Five robots were placed equidistant from each other at integer values symmetric at zero facing in the y-positive direction--each robot becoming a moveable point on the coordinate plane. Students entered the y-value into a command line interface (see Figure 1) to tell the robot how far to move in the y direction. The robot moved forward in response to positive values and backward for negative values. Students entered a shift value to align the robot positions with the quadratic function if the y-axis of symmetry was not at zero.

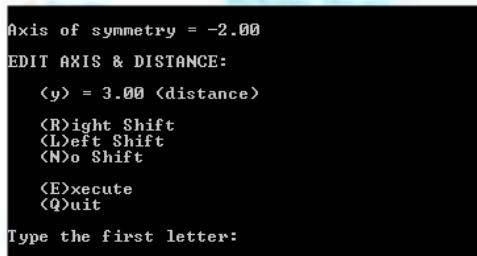
A pair of students, assigned to each robot, entered values into the command line interface and positioned and monitored the robot, pressing the "E" key to initiate robot enactment. The robot first turned and moved to the right or left to enact the shift value before facing in the y-positive direction and moving either backward or forward to enact the y-value. One researcher reviewed the audio and video recordings and field notes to identify a) students making connections between robot movement and mathematical meaning, b) evidence of collaboration, and c) evidence of joint construction of meaning.

## Results

Groups completed a total of 17 enactments during the 9 sessions with 7 enactments accurately modeling the quadratic function. Only 3 of the enactments involved shifting the axis of symmetry and all were unsuccessful. Connections made by students between robot motion and mathematical meaning fell into three categories: 1) the position of the robot on the coordinate plane, 2) the forward and backward motion of the robot for positive and negative values, and 3) the relation of the values entered into the computer and motion of the robot. We found little evidence of collaboration or joint construction of meaning. One student generally directed the activities of the others in a group, and connections between the robots and the quadratic function were voiced by the teacher rather than discovered by the students in the course of the activity.

## Number Line Activity Environment

The command line interface afforded minimal support for students to make connections between  $y$  and shift values and robot movement. To better support these kinds of connections the team envisioned a handheld device interface with an animated display in the mathematical space. To introduce support for collaboration a Hubnet (Wilensky & Stroup, 1999) classroom network of iPod Touch handheld devices was connected to a NetLogo (Wilensky, 1999) server with a robot server extension.



```
Axis of symmetry = -2.00
EDIT AXIS & DISTANCE:
  <y> = 3.00 <distance>
  <R>ight Shift
  <L>eft Shift
  <N>o Shift
  <E>xecute
  <Q>uit

Type the first letter:
```

Figure 1. Quadratic Robots Command Line interface.

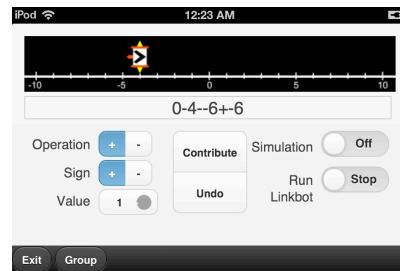


Figure 2: Number Line device interface.

The reassignment of the two pilot study to pre-algebra classes for the 2013-2014 school year, shifted the design focus to robots enacting integer expressions as movement along a number line. Groups of 2 to 4 students jointly construct integer expressions by entering values into the hand-held device interface (see Figure 2). The robot enacted the expression by turning in the direction of the operation and moving forward or backward depending upon the sign of the value. The expression  $4+3--2$  resulted in placing the robot at 4 on the number line before moving forward 3 units before spinning to face the negative direction and moving backward 2 units. This design built upon pilot study results showing that students talked primarily about robot position as points in the mathematical space and the relation between movement and positive and negative values.

Any device could be switch to simulation mode, causing the robot icon on the device to simulate the enactment of the expression, affording an intermediary opportunity for the student to connect the values they entered to robot motion without affecting other devices. The design encouraged a collective decision to execute the robot enactment by asking every student in the group to predict the end result and the highest and lowest values during the run. The device interface presented a comparison table of predictions and outcomes before setting the collective expression to the endpoint of the run.

## Discussion

The pilot study indicated that students primarily discussed the location of the robot as a point in mathematical space and the relation between the direction of motion and the sign of the values they entered. The Number Line activity design refines and extends the opportunity to examine these relations by asking students to predict the outcome of the run and by enacting both the operation and the sign of the value in the motion of the robot. Connecting the robots to a classroom network server supports opportunities for joint meaning construction and collaboration. We think robot movement in combination with an appropriate user interface and network infrastructure can support mathematical meaning construction, both jointly and individually, and provide unique opportunities for collaboration. We implemented the Number Line activity environment in the classrooms of the same two teachers in mid-November, 2013, and have included the preliminary results in the poster.

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## Acknowledgements

This work is supported by the National Science Foundation. Findings and opinions are those of the authors.

# Predicting Performance Behaviors during Question Generation in a Game-Like Intelligent Tutoring System

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**Abstract:** The present research investigates learning constructs predicting performance behaviors during question generation in a serious game known as Operation ARA. In a between-subjects design, undergraduate students ( $N=66$ ) completed the three teaching modules of the game, teaching the basic factual information, application of knowledge, and finally question generation about scientific research cases. Results suggest that constructs such as time-on-task, discrimination, and generation along with type of instruction (factual vs. applied) impact student behaviors during question generation.

## Introduction

Research in the learning sciences suggests that generating good questions about difficult conceptualizations contributes to deep-level learning. However, students rarely generate deep and relevant questions (for a review see Graesser, Ozuru, & Sullins, 2009). The goal of the present research is to discover predictors of performance behaviors during question generation within a serious game known as Operation ARA (Millis et al. 2011, Halpern et al., 2012). Operation ARA teaches 11 topics of research methodology using natural language tutorial conversations in a game-like atmosphere. The system includes three separate modules, teaching the basic factual information (Cadet Training module), application (Proving Ground module), and question generation about research cases (Active Duty module). Previous research on Operation ARA has shown differences between as well as modules (i.e. Cadet Training vs. Proving Ground) within the game. Specifically, differences in learning gains across these three modules are correlated with performance on three time-honored cognitive constructs known as time-on-task, generation, and discrimination (Forsyth et al., 2012). Additionally, variations in types of learning (deep vs. shallow learning) has been shown between the two modules suggesting that the Cadet Training module teaching factual information correlates with shallow learning and the application module (Proving Ground module) teaches deep-level learning (Forsyth et al., 2013). Previous research in the learning and cognitive sciences has shown relationships between these three constructs and learning in various learning environments requiring memorization of facts as well as application of knowledge (Pashler et al., 2007; Cepeda et al., 2006; Graesser, Conley & Olney, 2012). In the current study, these three cognitive constructs as well as the effect the other modules teaching factual and applied information on research methodology (i.e. Cadet Training and Proving Ground) are used to predict performance during question generation in the Active Duty Module of Operation ARA.



Figure 1. The interactive training modules of Operation ARA

## Methods

In the current study, 66 undergraduate students interacted with Operation ARA in a between-subjects, counter-balanced pretest-intervention-posttest design. While all of the students completed the assessments, the interaction between learning modules varied depending on the condition. The four conditions included the following combinations of modules 1) Cadet Training and Active Duty, 2) Cadet Training, Proving Ground, and Active Duty, 3) Proving Ground and Active Duty, and 4) Active Duty only. The logged data from these

interactions were used to assess the effect of the modules and cognitive constructs on behaviors during the question generation module (The Active Duty Module).

## **Analyses and Results**

In analyzing these logged data, we first correlated the performance on the three constructs within each module as well as the presence or absence of the other two modules (i.e., Cadet Training and Proving Ground) with the performance metrics in the Active Duty module. Next, we conducted a forward stepwise regression using the significant correlates as predictors on the three cognitive constructs within the Active Duty module. The results revealed that higher word generation ( $t = 3.86, p <.001$ ) and the absence of the Proving Ground module ( $t(66) = -5.50, p <.001$ ) significantly predicted higher generation during the Active Duty module ( $F(2, 64) = 15.21, p <.001, R^2=.32$ ). Alternately, it was the absence of the Proving Ground module ( $t(66) = -2.714, p <.05$ ), less words generated ( $t(66) = -2.52, p <.05$ ) and less time-on-task ( $t(66) = -2.53, p <.01$ ) in the Cadet Training Module that significantly predicted higher time-on-task in the Active Duty Module ( $F(3, 63) = 11.68, p <.002, R^2 = .33$ ). No statistically significant predictors were discovered for discrimination in the Active Duty Module.

## **Discussion and Future Work**

The present work discovered statistically significant predictors for the performance behaviors for generation and time-on-task during question generation. These findings are significant to the learning sciences community because it is extremely important and unfortunately uncommon for students to generate good questions. These results may help researchers and educators encourage question generation behaviors in classrooms as well as artificial environments. For example, educators may devise tasks requiring students to contribute more thoughts and information while applying knowledge rather than while simply memorizing factual information to encourage students to generate more questions. With increased question generation, students may be able to obtain a deeper-level understanding of important concepts.

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## **Acknowledgements**

This research was supported by the Institute for Education Sciences (R305B070349, R305C120001) and National Science Foundation (REC 0106965, ITR 0325428, HCC 0834847). The opinions expressed are those of the authors and do not represent views of the IES and NSF.

# Promoting Science Identification and Learning through Contemporary Scientific Investigations Using Practice-Focused Instruction

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**Abstract:** With major policy documents making ‘the practice turn’ in science education, this paper foregrounds how learners come to engage in scientific practices through immersion in learning environments that build upon prior interest and identity and focus on these strands of learning in relation to conceptual and epistemic knowledge development as youth participate in disciplinary practices. Scientific practices, conceptualized as a subset of social practices, are arrangements of comprehensible and comprehensive ways of knowing and doing. The links and separations between the social practices present in learning environments serve to structure the nexus of practices and allow for the tracing of engagement, participation and learning (Bell, et al., 2012b; Dreier, 2009). I report on analysis of students’ practice-related artifacts.

## Introduction and Rationale

The *Framework for K-12 Science Education* (NRC, 2012) calls for the focus on science and engineering education to be learning in practice. The release and subsequent state-level adoption of the *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013) bring forth to need to understand how all youth learn through practice. What types learning environments support learning in practice? What resources do students and teachers need to support their engagement in practice-focus instruction? This shift to focus on scientific practices in science education can be used to support an educational equity agenda. Broad inequities in science achievement exist for youth from non-dominant communities. And yet, all youth should be to use science and scientific thinking in their everyday lives and, if they choose, in pursuit of science, technology, engineering, and mathematics (STEM) careers. Sociodemographic diversity in the STEM fields do not mirror the diversity of our society—although we know that broadening participation in STEM will improve the scientific knowledge that is produced (NSF, 2008). There are broad-scale challenges associated with improving opportunities to learn for all youth, especially those coming from non-dominant communities.

In learning environments, specifically schools, this means promoting powerful, inclusive science learning experiences for youth. Sociocultural and sociocognitive theories of learning (Vygotsky, 1986) have identified educational design principles that can be productively used to cultivate powerful learning environments. We know from sociocultural research that all significant learning involves identification processes as people participate in social practices (Lave & Wenger, 1991). This perspective on learning – often referred to as “the practice turn” in science studies foregrounds how learners come to engage in scientific practices.

## Theoretical Framework: Designing from Multiple Structures of Social Practice

Practices are collective actions that exist within a nexus of contexts that people and artifacts travel across and they are affected by the instructional and historical natures of those contexts. Practices have norms, tools, and resources and are interconnected in localized networks that change and are altered by participants over time. Dreier’s theory of social practices situates practices in the complex interactions of people in the social world, across the contexts of their lives (Dreier, 2009). People live and participate in multiple diverse contexts and these contexts are socially and materially arranged to allow for particular practices to occur within them, together the contexts are separated or linked from other practices in a “comprehensive structural nexus of social practice” (Dreier, 2009, p. 196). This work maintains a focus on social practices in learning experiences. Students’ participation is contextualized within four sets of partially aligned and competing bundles of social practice present in the learning environment: (1) contemporary professional scientific practices, (2) school practices, (3) youth and community practices, (4) the practices of relevant social domains. The framework approaches practices as patterns of activity that are influenced by the contexts of the performers, the goal of the interaction in which the practice takes place, and the interactions with other practices (Rouse, 2007).

## Methods and Data

This study is design-based research analyzing one project-based unit that is part of the year-long introductory Biology course. The educational intervention consists of a yearlong introductory Biology course designed around five project-based instructional units delivered on a social media technology platform. During the beginning stages of development, units were piloted individually in a collaborative co-teaching model with

researchers in the classroom each day. This analysis is of the pilot of the DNA barcoding project that lies within the eight-week long genetics unit. The study consists of four analyses: (1) quantitative analysis of pre- and post-test scores and student-reported engagement data, (2) analysis of practices over the course of the unit, (3) analysis of student work, and (4) two case studies of groups of students across the cascade of practices that unfolds in the unit. A subset of the analysis of student work is presented in this poster. The analysis is from the full Spring 2012 data corpus for this unit that includes: student work and class performance data, approximately 31 hours of video, student artifacts from 11 groups (4 students per group), one student focus group, and interviews with four students and one teacher. This enactment of the unit took place with five biology classes in a public, urban high school in the Pacific Northwest.

## **Analysis and Findings**

Analysis of student work occurred through coding based on key constructs from the literature (e.g., performances of scientific practices, statements of relevance), as well as other written statements I identified as important to performance of practices (e.g., instances of connections between practices). Analyzing the conceptual theme representations allows us to understand the prevalence of the practices as mirrored in the student artifacts. I interpreted the patterns of indicators present for student engagement in scientific practices, school practices, everyday practices, and their referencing of relevant social domains.

The curriculum was designed to engage students in specific epistemic practices of science in ways that were motivated by the investigation they were conducting. The scientific practices that students clearly engaged in as they completed the two documents were Planning and Carrying Out, Investigation and Obtaining, Evaluating, and Communicating Information, and Constructing Arguments from Evidence. Not surprisingly, this strongly fits with the instructional design focus of the unit. Unlike traditional school science investigations, however, these practices co-occurred and students employed the outcomes of one practice to inform their engagement in another practice. For example, students decided what type of investigation they would pursue, agreed on a focus to that investigation, obtained and evaluated information related to their investigation, reflected on how that information informed or brought up questions or concerns about their investigation, and continued to search for and cite information in their proposals for continued funding.

## **Conclusions and Scholarly Significance of the Work**

By engaging in extended investigations that required participation in the epistemic practices of science, students were able to engage in a sensible ‘cascade of disciplinary practices’ (Bell et al., 2012a). There were significant linkages and separations between the bundles of practices in play in the learning environment. This work contributes to helping understand how to take the practice turn in ways that are personally compelling to youth and connect them to more authentic forms of work of professional science. This is a new instructional model for the field that cultivates powerful learning environments in formal education and explicitly focuses on science identification.

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# **Creating Material Representations of Practice at the Boundary of Professional Development and Classroom Practice**

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Large-scale observational studies in American science classrooms have documented there is a general focus on activity rather than sense-making discourse and that teachers seldom press for explanations (e.g. Banilower, Smith, Weiss, and Pasley, 2006). Reform efforts to impact teachers' activity in classroom have largely focused on standards and curricula designed to encourage and support enactment of sense-making pedagogies in the science classroom. Standards and curricula are tools that largely focus on the planning phase of the teaching process, without being designed to have intentional support for the individual reasoning of learners in local contexts. There has been little research focusing on the local creation or revision of tools of enactment teachers use to support their students' science explanation making. In this study we report on a yearlong professional development project with teams of middle and high school teachers who focused on the practice of *supporting students in generating evidence-based explanations*.

The teachers engaged in iterative design cycles as they modified tasks, tools, and classroom talk (Sohmer, Michaels, Connor and Resnick, 2009) with a goal of supporting their students in generating evidence-based explanations. Their work was done in the context of job-embedded professional development (PD) with studio-days. During Studio Days, multiple role-actors (classroom teachers, coaches, researchers, and university staff) collaborate to provide real-time feedback within current lessons. Our analysis focuses on the way two kinds of tools, formative enactment tools and face-to-face tools, act as reification and stabilization for the practices of supporting their students in generating evidence-based explanations.

## **Theoretical Framework**

The analytical frame we use to examine the teachers' activity during studio days is professional vision. Goodwin (1994) described professional vision as "the discursive practices used by members of a profession to shape events in the phenomenal environment they focus their attention upon" (p. 606). In particular it consists of three practices: *highlighting* – marking as salient specific phenomenon in a complex context; *coding* – transforming materials being attended to into objects of knowledge; and *producing material representations* (inscriptions). These practices allow groups to structure and organize the social world around them into professionally meaningful patterns of practice.

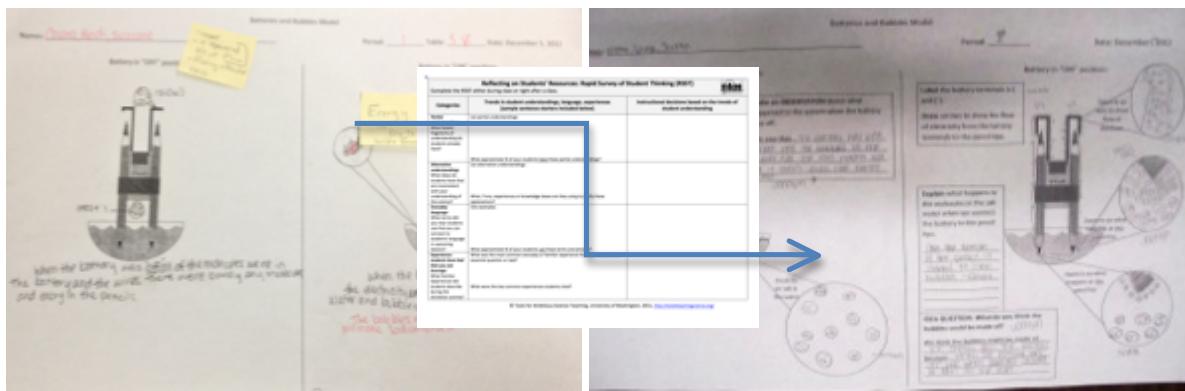
Goodwin's (1994) notion of professional vision has been used as a way to conceptualize teacher learning (e.g Lobato, Rhodehamel, and Hohensee, 2012). Much of this literature, especially that of noticing has focused on highlighting and, to some extent, coding (van Es and Sherin, 2008). That is, the focus is on what teachers attend and respond to in the complex activity of a classroom. One practice in Goodwin's framework, the production and articulation of material representations, has received little attention in the literature on teacher learning. This study examines teachers collaboratively creating and revising particular material representations of practice (formative enactment tools and face-to-face tools) as a way of understanding their enacted professional pedagogical vision (PPV). Using the analytical lens of PPV, and specifically material representations of practice, can provide insight into how teachers make intentional changes to tools that support targeted learning experiences for students.

## **Formative and Face-to-Face Tools**

The goal of each Studio Day is the co-creation of tools, tasks and talk that support students in creating evidence-based explanations of scientific phenomena (Windschitl, Thompson, Braaten and Stroupe, 2012). For teachers and others attending studio days this means engaging in multiple rounds of co-planning, co-teaching, and co-debriefing. This involves: 1) unpacking scientific content and developing a shared understanding of different levels of a scientific explanation students might supply, 2) debriefing how students are learning using formative tools such as a Rapid Survey of Student Thinking (RSST), and 3) developing/refining face-to-face tools that teachers provide to students support for their written explanations of scientific phenomena. As an initial step we used activity theory to analyze the function of formative and face-to-face tools in terms of their relationship to the object of work, subjects and roles, and rules governing actors/routines (Engestrom, 2004).

- Formative tools (e.g. RSST, see Figure 1)
  - *Object of work:* Understand and unpack students' ideas and support modification of face-to-face tool
  - *Subjects and Roles:* Group of teachers and coaches, video of productive conversation between students and student work samples

- *Rules that govern interactions among actors/routines:* Gathering students ideas (partial understandings, alternative understandings, everyday language and everyday experiences) without engaging in “repair talk,” ways of fixing lessons
- Face-to-face tools (e.g. electrolysis model, see Figure 1)
  - *Object of work:* Mediating students’ productive conversations and written explanations
  - *Subjects and Roles:* Students, teachers, explanation of a scientific phenomenon
  - *Rules that govern interactions among actors/routines:* Students’ ideas are considered resources for explanation building, some parts of the scientific explanation (e.g. why level explanations) are more important than other



**Figure 1.** Iterative revision of face-to-face electrolysis model mediated by the RSST tool

## Discussion

The role of tools in professional development and student learning has been under theorized and under examined in the context of large-scale pedagogical reform. We believe that framing teachers work with tools in terms of professional pedagogical vision, with particular focus on material representations of practice foregrounds the importance of tools as a way of improving practice, both within and across activity systems. This analytical frame allows for the investigation of how these tools are mutually reinforcing across professional development and classroom contexts. By foregrounding material representations of practice, we can better see how tools contribute to the reification and stabilization of practices. In particular, we can differentiate between meaningful iterative mutually reinforcing tool systems from less productive version, such as:

- *nominal appropriation* of tools and routines without adoption of the purpose of generating and revising scientific ideas
- *well intentioned tools* that don’t fully support students in generating and revising scientific ideas
- adoption of tools *independent of* mutually reinforcing, iterative routines outside of a tool system

Educational reform efforts have invested massive amounts of resources into professional development and curricular materials. Reframing the activity of teachers as they engage with these curricular materials in professional development contexts to focus on how they develop and use tools and systems of tools allows us to differentiate productive uses from lethal mutations. Focus on PPV with particular attention to material representations of practice has the potential to expand practice-based theory of teacher and student learning across contexts.

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# Examining How Students Make Sense of Slow-Motion Video

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**Abstract:** Slow-motion video is starting to appear in science classrooms as a source of data for students to examine. However, seeing important features in such video requires a particular kind of student engagement and supported acts of noticing. This poster reports on an exploratory study of what students noticed and talked about when viewing slow-motion video during a classroom design experiment focused on bodily activity as it relates to motion and animation.

## Introduction

Slow-motion video (SMV) is an important way for scientists to analyze physical phenomena (e.g., Mazur, Krehbiel, & Shao, 1995). SMV is created when cameras capture motion at high framerates (>120 frames per second); when this video is played back at a standard rate (~30 fps), the motion is slowed. As prices drop for camera equipment necessary to generate high quality SMV, such video is being integrated into school science curricula (e.g., Heck & Uylings, 2010). With SMV capture capabilities being built into smartphones and other mobile devices (e.g., point-of-view cameras), we expect more classrooms will turn to SMV as a source of data for students to use during classroom inquiry experiences. These SMV capture devices can facilitate students' noticing and observing of complex phenomena that are otherwise invisible, such as the frequency of oscillation in the intensity of a light bulb and the detailed body movements when throwing a baseball.

While SMV is widely appreciated because it maintains high fidelity and detail relative to the original actions being recorded, specialized ways of seeing need to be developed in order for SMV to actually be useful. Professional disciplinary communities are sometimes noted for their ability to coordinate visual artifacts in very particular ways as part of their work (Stevens & Hall, 1998), and researchers have developed various terminology, such as "professional vision" (Goodwin, 1994) and "noticing" (Sherin & van Es, 2005), to describe how professionals develop selective perceptions of specific situations. Such research suggests that for students to be able to productively work with SMV, they must also learn to see and notice aspects of the video in particular ways. This study reports on a classroom design experiment around the topics of movement and animation and asks how students discuss and make sense of SMV.

## Designed Unit and Data Sources

The design experiment took place at a public charter elementary school in the United States Intermountain West as an extension to other work we have done with elementary students examining data related to the human body (Lee & Thomas, 2011). Fifteen fifth grade students from two classrooms participated in the unit. Over 13 days, the students met one to two times per week to examine and discuss SMV footage of a bouncing ball, a vertical jump, and other idiosyncratic bodily movements that they performed. Following the SMV discussions, students modeled the movements as they noticed them using stop motion animation software (SAM Animation, Searle, Gravel, & Rodgers, 2009).

All lessons in the unit were video-recorded. Whole-class discussions of SMV comprise the focus of this poster. In this poster, we report on the conversations and actions related to SMV of a vertical jump, which covered approximately two hours across three days.

As an assessment for the unit, students created flipbooks showing a realistic jumping motion at the beginning and end of the unit. These flipbooks also served as an initial object for class discussion and to help orient the students to the theme of animation. Researchers scored the flipbooks using a rubric that included epistemic fidelity, consistency, and conventionality of students' drawn representations.

## Findings and Discussion

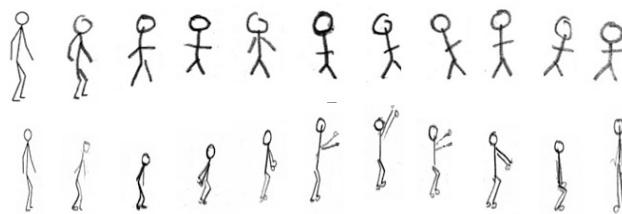
The students engaged with the SMV in several ways. Two of the most prominent ways were physically re-enacting the depicted motions and comparing jumps across types and students. Students used physical re-enactments to supplement their explanations in front of the class. During one discussion after watching video of a student's jump, students noted that one of the jumper's arms moved upward. However, there was disagreement about which arm it was; one student stood up, oriented himself in the same way as the jumper in the video, and then moved his arm to demonstrate which arm he thought moved. In response, another student came to the front of the room to model the jumping motion while also adopting the same position and orientation as the jumper in the video (Figure 1). Soon, other students began to explore the movement themselves.



**Figure 1.** Students immediately re-enacting the slow-motion jump to determine how a jumper's arms were moving.

Students also engaged with the video by comparing across different students' jumps for both common and different movements. They chuckled at odd movements, and they also noted that those odd movements were idiosyncratic. By looking across multiple examples, the students were able to find commonalities across jumps, which they discussed further and used later in their stop motion animations.

These stop motion animation videos were of variable quality with some inconsistencies across groups with respect to what jump features were depicted. However, when the students' post-unit flipbooks for depictions of a horizontal jump were assessed, there was a significant improvement ( $t=-3.68$ ,  $df=12$ ,  $p<.001$ ). Figure 2 illustrates changes in a student's pre-unit and post-unit flipbooks.



**Figure 2.** Excerpts from one student's flipbook before (top) and after the unit (bottom).

In light of these results, this initial effort seems to suggest that the use of slow motion video does have promise. The full range of strategies for making sense of such video still needs to be explored, but it appears that re-enacting motions viewed in slow motion and comparing multiple examples of the same phenomenon may be important ways for students to relate to and interpret information in this medium.

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## Acknowledgments

This work was funded by NSF grant DRL-1054280 and the Marriner S. Eccles Foundation. The opinions in this paper are those of the authors and not necessarily of any funding agency.

# **Identity, Digital Learning Environments and Academic Success**

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**Abstract:** A student's identity significantly influences their attitude and behavior towards academics regardless of abilities. This paper proposes a framework for the design and evaluation of digital learning environments (DLEs) that explicitly promote identity construction related to academic success. Subsequent research can address three questions: (1) How does one's identity affect how they interact with DLEs? (2) Which aspects of DLEs best promote identity construction? and (3) How does exploring issues around identity affect learning outcomes?

## **Problem Statement and Theoretical Background**

As many scholars have found, identity is a crucial component of learning. As the use of technology in classrooms grows, it is important for researchers to gain a better understanding of how interacting with digital environments affects learning as it relates to identity construction. Pulling from research on identity and academic success as well as identity and digital learning environments (DLEs), I propose design principles and elements to guide the development of future DLEs that cultivate identity and academic success. Subsequent research related to these DLEs will be able to address three questions: (1) How does a person's identity affect how they interact and learn with digital environments? (2) What aspects of virtual learning environments best promote (and hinder) identity construction? and (3) How does exploring/addressing issues around identity affect learning outcomes? I believe that in answering these questions, educators and design-based researchers will be better able to understand and meet the needs of learners, conceivably allowing for greater learning gains.

## **Identity and Academic Success**

Identity construction is a fluid and ongoing process of exploration (or evaluation) and commitment. Wenger (1998) states that "It is in that formation of an identity that learning can become a source of meaningfulness and of personal and social energy" (p. 215). Therefore, to be most effective, teaching practices need to incorporate instructional elements and activities that make explicit the ways in which academic content is related to students' everyday lives. Specifically, cultural identity, a subcomponent of one's collective identity, is important to consider since it can be in opposition of academic success. For example, conflict between a student's home culture and what is expected of them in the school culture has been identified as part of the reason for school failure (Bransford, Brown & Cocking, 2000). Each subcomponent of a person's identity holds a certain salience in relation to the collective identity. Certain environments and interactions can temporarily change the salience and relevance of an identity so that particular characteristics and commitments are given preference (Spears, 2011). Also, the ideas a person holds about their future possible selves depend on environmental affordances and constraints and, as a result, are constantly revised (Oyserman & James, 2011).

## **Identity and Digital Environments**

There are three ways in which digital environments have been positioned in the research that have implications for use in improving academic success: digital environments as mirrors, digital environments as exploratory tools, and digital environments as construction tools. In *The Second Self*, Turkle challenged the then widespread idea that a computer is "just a tool" by proposing that we view a computer "as an evocative object" (Turkle, 1984, p.19), and asserted that using a computer "changes people's awareness of themselves, of one another, of their relationship with the world" ultimately resulting in viewing the computer as a second self (p. 18). Berman and Bruckman (2001) proved the exploratory capacity of digital environments with their study of an online game where users are assigned a gender and must prove their identity to others and single out the imposters. While some participants used the game to explore their ideas of their ideal self, others explored ideas of their ideal or actual mate. Therefore we can conclude that digital environments hold great potential to help students explore aspects of their identity. Lastly, the three-dimensional environment Zora (Bers, 2006) is a prime example of a construction tool. Zora allows users to design the objects, characters, spaces and values of a virtual city that they then inhabit – activities that the author asserts promote competence, connection, character, confidence, caring, and contribution (Bers, 2006). These components are linked throughout the identity literature as being supportive of identity achievement (e.g., Vignoles, Schwartz & Luyckx, 2011).

## **Designing for Learning and Becoming in Practice**

To promote the development of a constructed identity, and in turn academic success, DLEs need features and activities that integrate the positions of mirror, exploratory tool, and construction tool. Influenced by the design guidelines of Zora (Bers, 2006), I offer possible design principles and particular embodiments of the principles.

## **Design Principles**

- I. Promote positive development of identity
  - 1) Provide dynamic, diverse and flexible computational tools with which users can interact and identify
    - a. Encourage users to create complex representations of the self and identity in various ways
    - b. Encourage users to explore powerful ideas about the self and identity, highlighting the multiplicity of aspects and changes over time.
    - c. Include personally relevant and salient information
    - d. Provide a wealth of academic content and activities situated in real-world contexts
  - 2) Ensure a safe and supportive environment/community
    - a. Establish guidelines for respectful communications between users
    - b. Celebrate and support diversity among users
    - c. Identify and enlist the support of more knowledgeable others in the digital community

## **Design Elements**

- 1) *An interactive and customizable interface (Design Principle 1a)* – A customizable interface creates a space for the user to explore, create and reflect on identity aspects (Bers, 2006). The persistence of the interaction encourages the user to regularly reevaluate the accuracy of the representation.
- 2) *A user created avatar and profile (Design Principles 1a & 1b)* – an avatar acts as a mediator between the user and the digital environment by serving as a portrayal of the user stylized in the same manner as the rest of the environment. The profile presents the user's most salient identity aspects in one space. These aspects also prompt the user to reflect on how they understand and choose to represent their actual and ideal selves, which is important for learning (Bransford, Brown & Cocking, 2000).
- 3) *Portfolio: An indexed artifact reservoir (Design Principles 1a & 1b)* – this feature allows users to collect and store any artifacts from the learning environment (e.g., a completed activity or a forum thread) as well as items from other sources. As it develops, the portfolio will support reflection and help the user create a narrative about their identity (Bers, 2006).
- 4) *Journal: An active reflection space (Design Principle 1b)* – The journal provides a constructive outlet for the user's innermost thoughts. It also allows the user to review past entries and notice trends or major changes which can lead to improved metacognition and a more integrated identity.
- 5) *Academic content and activities (Design principles 1c & 1d)* – A student's skills or technical ability is a significant component of how users view themselves in relation to academics (Oyserman & James, 2011).
- 6) *Social networking tools (Design Principles 2a, 2b & 2c)* – Talking to various, more knowledgeable others can help users to change their beliefs about what is possible, learn best practices and also build a network of support and accountability, all of which are important for learning (Wenger, 1998).

## **Conclusion**

Academic success requires students to possess academic knowledge and skills as well as a constructed identity wherein salient and dominant identity components (e.g., cultural and ethnic identity) align with academic and disciplinary identities. As discussed, the necessary processes for developing a constructed identity can be facilitated by the affordances of digital environments. It falls to design researchers to devote more explicit attention to developing learning environments that incorporate identity constructing elements and activities. The design principles and elements discussed provide direction for future work in this area.

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# **Science Teacher Pedagogical Design Capacity with Technology in an Integrated Teacher Preparation Program**

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**Abstract:** This study unpacks a set of practices that impact preservice science teachers (PST) ability to incorporate technological resources into their planning in ways that support instructional episodes aligned with the goals and demands of an integrated teacher preparation program. Early results suggest that PSTs are able to develop the ability to plan high demand tasks using technology, pedagogical design capacity for technology, after instructional interventions in their teaching methods course.

## **Major Issues and Potential Significance**

With more and more teachers turning to non-traditional curriculum materials, such as online simulations, blogs, electronic readings, math games, ...etc., it is important for school administrators and teacher educators to understand how the technological resources teachers find and utilize are impacting the instructional episodes that teachers craft. This is especially true of new or beginning teachers. As others have detailed beginning or inexperienced teachers have a tendency to offload instruction from curriculum materials (Brown & Edelson, 2003; Forbes & Davis, 2010). However, if the materials they do offload do not align with the instructional practices promoted by district administrators, the possibility for drift from the intended type of instruction are highly likely (Brown, 2009). This project first asks is it possible to train preservice science teachers (PST) to identify the affordances and constraints of technologies for instructional purposes? Second, if this is possible, what impact does this knowledge have on PST's instructional design choices? In other words, are PST's design choices resulting in instructional episodes that fit the mold of instruction being presented by their teacher preparation program?

Further, this work contributes to our knowledge of how we prepare PST to utilize technology in three ways. First, by developing an understanding of students' ability to evaluate teaching technologies' instructional constraints and affordances we can better develop opportunities for them to practice working with technology. Second, by developing an understanding of how PST design instructional episodes around technology and how those decisions relate to the constraints and affordances of the technology, we hope to learn how to better support this design process. Finally, this work allows for the development of a way for researchers to code and identify students pedagogical design capacity (Brown, 2009) related to technology, further illuminating how teachers' instructional planning unfolds.

## **Theory and Method**

Traditionally, curriculum materials have been considered "instructional resources such as textbooks, lesson plans, and student artifact templates" developed by experts with the specific intent for how these materials should be used (Forbes & Davis, 2010, pg. 820). Sherin and Drake suggest that as teachers use curriculum materials they develop what is called "curriculum vision" (2009). This is the teachers' ability to evaluate and utilize curriculum materials to enact certain types of instruction, which meet the specific instructional goals they desire. Brown suggests that this ability to have teachers "perceiving affordances, making decisions, and following through on plans" is their Pedagogical Design Capacity (Brown, 2009, pg. 29). It is believed that teachers' Pedagogical Design Capacity (PDC) is developed over time with continuing enactment of curriculum, aka more practical experience, and through better-designed curriculum materials (Brown 2009). This study takes the framework of PDC and applies it to non-traditional curriculum materials, specifically, classroom technology in K-12 science classrooms.

Utilizing an exploratory qualitative based study, the context for this project is a Science Teaching Methods course at a large Midwestern University. The purpose of the course was ultimately to support preservice science teachers (PST) ability to plan and implement instructional episodes that incorporated high cognitive demand tasks in ways that encourage K-12 students to engage with difficult science content in productive ways. Others have shown that implementing high demand tasks in mathematics settings results in positive learning gains for students and incorporating this framework in science education has shown early signs of success (Stein, Grover, & Henningsen, 1996; Cartier, et al., 2013). In order to prepare PST to design such instructional episodes, the course utilized a framework that included cycles of representation, decomposition, and approximations of these technology practices (Grossman et al., 2009).

For this study, we first asked PST to design a lesson using a technology of their choosing (Pre Lesson Plan). This planning came before any instruction around the technology practices and was meant to establish a baseline of PST initial ability to plan with technology. PST then participated in an inquiry activity around

classroom technology, specifically simulators. The course instructor modeled appropriate inquire-based questioning and facilitating practices around the use of the simulator. In the second part of the same class PST participated in a discussion about technological affordances and constraints, planning highly demanding lessons with technology, and issues with carrying out instruction with educational technology, most of which was related back to the simulator activity. This entire lesson was video recorded and transcribed. At the completion of the lesson we asked the PST to revise the lesson plans they had previously turned in as they saw fit based on the discussions in class (Middle Lesson Plan). Finally, two weeks after the class period on technology practices, we then asked PST to implement a lesson with their K-12 students that involved "Students engaging with technology in a way that promotes learning that would not otherwise be possible without the use of the technology." After, we asked the PST to select technology that supported student engagement in a high cognitive demand task, and consider the constraints of their selected technology and setting during their planning. Finally, the PST created artifact packets (Borko et al., 2005), which included lesson plans, supporting documents, supervisor feedback, and reflection for this lesson (Post Lesson Materials).

We are currently coding data using emergent coding for PDC from the video transcripts and written lesson plans. The codes are based on the ideas from Brown and Forbes & Davis and have been based on examples of how PST demonstrate the different abilities to design instruction around the simulators or technology in their posted lesson. The coding indicates that 8 of 15 PST showed marginal development, 2 of 15 showed large growth, and 5 of 15 showed limited development of PDC for technology. Although most (13 of 15) of the PST were able to cite limitations of the technology they chose related to their classroom context, only 4 were able to identify affordances that would justify using the selected technology. The underlying reasons for this gap is still be explored in the second phase of coding

## **Early Results and Relevance**

Early data analysis suggests that PST are able to make connections between the affordances and constraints of technology in relation to the instructional planning they complete after participating in structured course experiences. Early results also suggest that almost many of the students still struggle with integrating technology in ways that maintain the desired instructional practices forwarded by the teacher preparation program, specifically maintain high demand tasks that front scientific thinking. These results inform the design practices used in teacher preparation programs around technology and have the potential to shape the technology implementation practices of K-12 Preservice teachers. Unpacking the steps and processes that allow PST to carry out these practices is critical for producing well-started teachers who use technology in ways that align with the instructional goals of districts and teacher preparation programs.

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# **Family Creative Learning: Engaging Parents and Children as Learning Partners in Creative Technology Workshops**

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**Abstract:** In this poster, we present preliminary findings from Family Creative Learning, a series of intergenerational workshops for parents and children to participate in design-based activities using creative technologies such as the Scratch programming language and the MaKey MaKey invention kit. The workshops are collaboratively and iteratively designed with staff at community centers that serve families with limited resources and social support around computing. Case studies of families' participation highlight the ways in which parents and children can support each other in their learning experiences with computing.

## **Introduction and Background**

Design-based activities with computing can introduce young people to creative possibilities, enabling them to not only *read*, or use and interact with technology, but to *write*: to create and express themselves with technology. As they create with technologies, they learn computational concepts and practices and gain new perspectives into the dynamics and processes behind the technologies they use (Brennan & Resnick, 2012; Wing, 2006). Such fluencies are essential in our increasingly digital society.

While many youth are interacting with technology, studies suggest that only some youth are engaging in design-based activities with computing (Livingstone & Helsper, 2007). Youth with social networks who can help them navigate information and opportunities to further engagement, such as parents with careers in technology-related fields, are at a greater advantage to deepen their interaction with technology (Hargittai, 2008). And while researchers have investigated the kinds of roles parents can play—from acting as resource brokers to serving as collaborative learning partners with young people (Barron, Martin, Takeuchi, & Fithian, 2009)—these studies often examine families where at least one parent has a job in the technology sector.

This research explores how to provide opportunities that support the engagement of families who have limited resources and social support around computing. This paper describes Family Creative Learning, a series of intergenerational workshops that engage children and parents in design-based activities with computing using tools such as Scratch, a programming language for children to create their own interactive media such as games, animations, and stories (Resnick et al., 2009). These workshops are designed in partnership with community centers that serve primarily low-income families of color, who have limited access to resources and social support around computing. The current study focuses on the following research question: *How do parents and children support each other in the collaborative design-based activities of the workshop series?*

## **Workshop Design**

Family Creative Learning consists of five workshops in which parents and children engage in design-based activities with technologies. The workshops are grounded in constructionist learning theory, which argues that people learn best when they build personally meaningful artifacts in collaboration or interaction with others (Papert, 1980). Each session builds on the previous one to support parents' and children's development not only in using the tools, but working together to create projects with those tools. The format of each workshop session is split into four parts: (1) **Eat**: Families eat dinner together provided by a local restaurant; (2) **Reflect**: Parents and children divide into two groups and facilitators "check-in" with parents and children separately; (3) **Make**: Families engage in design-based activities using Scratch programming language and MaKey MaKey invention kit; (4) **Share**: Families share their projects and ask each other questions or give feedback.

In the first two days, parents and children work separately on simple Scratch projects. On the third day, parents and children work together on a Scratch and MaKey MaKey project. On the fourth day, parents and children design their own projects with the tools to share at a community showcase on the fifth day.

## **Methods and Participants**

We used qualitative methods to document the workshop process and understand the participants' experiences. During the workshop series, we gathered observations from facilitators and conducted group interviews with parents and children separately during the 15 minute "Reflect" part of the workshop. After the workshop, we conducted 1-hour semi-structured individual interviews with parents and children about their participation.

We implemented the workshops of the current iteration in a Computer Clubhouse that is housed in a community center for urban youth. Computer Clubhouses are informal learning centers where youth engage in creative activities with technology (Kafai, Peppler, & Chapman, 2009). In the community served by this

Clubhouse, at least 80% of the members live in households that are under 200% above the poverty line. At least half of the members live in single-parent households, of which at least 90% are single-mothers. We primarily recruited children between the ages of 8 and 12, but welcomed their younger and older siblings to join the workshop. Five families participated in the workshop series for a total of 15 unique participants with five parents (4 mothers, 1 father; ages 31 to 58) and 10 children (4 girls, 6 boys; ages 3 to 13). Four of the parents were women, and two were single mothers. Three of the families self-reported as Hispanic/Latino and were first-generation immigrants. The other two families self-reported as White. All five families continued participating through the last day with the community showcase.

## Case Studies of Family Participation

In this poster, we share case studies (Yin, 2009) of families from the workshop series. These case studies describe their attitudes before the workshop, their experiences working with the computing tools and collaborating on a project, and their reflections on their experiences.

Overall, we found that families interacted in a variety of ways that reflected how families can apply existing learning dynamics—dynamics that they may use during existing activities like homework help—into a new context like computing. At the same time, they could try out new practices as learning partners. For example, in one family, Rosa, a mother of two, came into the workshop feeling that she had nothing to contribute because her daughters were more savvy with technology. However, after working with her daughters on Scratch and MaKey MaKey projects, she began to see how her supportive learning practices, such as giving feedback, providing encouragement, and knowing when to step in to help them and step back when they were progressing on their own, could also be helpful in supporting her daughters' learning and designing with technology. Meanwhile, her eldest daughter, Clara, was trying on new learning dynamics as she supported her mother in getting started with Scratch. While she described feeling "kind of weird" helping her mother, who was older and usually the helper, Clara expressed how proud she felt—and noticed it made her mother happy too.

## Discussion

This research highlights design considerations in supporting learning experiences for families as a unit, particularly in the context of design-based activities with computing. Often computing outreach programs serve children or parents alone, without integrating the larger learning ecology that sustains learning in such activities (Barron, 2004). These workshops leverage the learning dynamics that families already use in activities like literacy development and support families in using them in the context of computing.

The case studies of families in these workshops suggest possibilities for intergenerational learning with computing. While parents initially described feeling unable to help their children with technology, they saw how they could apply practices they already used to help children learn. In addition, the design-based context enabled families to experience new dynamics, adding to their repertoire of family learning practices.

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## Acknowledgments

We would like to thank our community partners and volunteers as well as the families who participated in our Family Creative Learning workshops.

# **Teachers Becoming (Temporary) Engineers to Become Better Teachers**

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**Abstract:** The new science standards incorporate engineering practices, but few teachers are prepared to enact these. This poster presents preliminary findings from professional development that placed 14 teachers in university engineering labs for six weeks, tracking changes in their understanding of STEM practices, their designs for their classrooms, and the impact on their students. Preliminary findings demonstrate deepened teacher understanding of STEM practices and that their students begin with notions that do not match STEM practices.

## **Major Issues Addressed**

An increasing focus on engineering practices is evident in the Next Generation Science Standards (NGSS), (National Research Council, 2012). However, teachers are unprepared to enact these practices; few teachers have experience in engineering.

## **Significance**

This study builds on and extends what is known about how teachers and their students learn engineering practices and develop STEM identities. Engaging teachers in advanced STEM research can provide them with a deeper understanding of STEM and renew their enthusiasm for teaching, but can be difficult to bring back to the classroom (Blanchard, Southerland, & Granger, 2008; Johnston, 2003). The latter is crucial because research has shown that students who have an understanding of the core disciplinary practices- in this case, design- are likelier to persist through a challenging course of study (Stevens, O'Connor, Garrison, Jocums, & Amos, 2008).

Learning is a coupled act of identity; who you are affects what you learn, but what you learn changes who you are (Wortham, 2006). Authentic experiences support the development of engineering (Pierrakos, Beam, Constantz, Johri, & Anderson, 2009). We build on past research to investigate how engineering practices were taken up by teachers and their students, and how STEM identities developed.

## **Methodological Approach**

### **Participants and Setting**

Participants include K-12 teachers and their students. At the time of writing, consent forms for teachers are still being returned, with a maximum sample size of 14. Teachers were recruited from rural and urban schools serving students traditionally underserved and underrepresented in engineering. As part of the application process, they submitted a letter from their principal committing to allow the teachers to implement project-based engineering units in their classrooms. The teachers spent six weeks in a university engineering lab conducting research as a lab member and designing project-based units to bring the lab experience back to their schools. They were provided seven days of professional development on designing relevant project-based units.

### **Measures and Analysis**

The teachers completed a daily end-of-day survey to provide brief snapshots of their experiences and information about with whom they interacted; this will be analyzed using social network analysis and open coding. They also completed a pre and post survey that provided a detailed picture of their understanding of STEM practices (150 questions, with 20 constructed response items). The teachers are providing deidentified reports of student responses to a shorter survey that asks related questions. To date, two teachers have provided these data and analysis of all data is in progress.

The survey given to the students asked four open-ended questions: how they thought the work they did in their classes mimicked what an engineer did, what they might be doing if they were scientists working in a lab like the one their teachers visited, and they were asked to define science and engineering. Likert-style questions included items that asked the students to rate their understanding of what they did in the classroom, how much the teacher guided their inquiries, and about their future intentions of going into the STEM fields. Likert items were analyzed using basic descriptive statistics and will be compared to post-unit responses and teacher responses. Open coding of the qualitative data is ongoing.

## Findings, Conclusions, and Implications

Preliminary findings suggest that the research experiences teachers had varied by lab. Some mentors were excited to have a teacher present, while others were not. The teachers all learned a great deal about social norms and the realities of lab work, including: (1) lab work occurred in evenings and weekends, but rarely in the early morning hours the teachers preferred to keep; (2) much time is spent waiting for experiments to happen; (3) equipment and materials are highly specialized and costly and require training prior to use; (4) the experiments they conducted led to highly specific, complicated results. They therefore initially struggled with how to bring the experience back to their classrooms. Because the professional development also focused on ways to make STEM practices meaningful and relevant, most teachers found ways to accomplish this in their unit designs.

Preliminary analysis of student surveys completed prior to the units indicate that few students are interested in becoming STEM professionals (Figure 1). Student descriptions of what it would be like to be in the lab revealed an understanding based in school experience, with little understanding of STEM practices:

- “I imagine it would be a lot like class; people would tell me what to do and I would have a little freedom to learn by myself.”
- “It would be very interesting but it would be the same that we are doing in our labs. But with bigger problems to solve.”
- “I think it would be really high tech and nice looking. I would just be helping to keep it nice looking.”

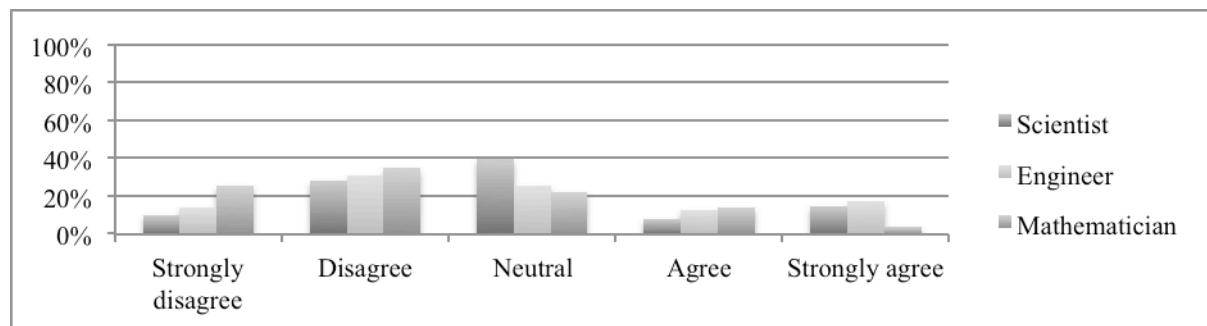


Figure 1. Student responses to “In future, I would like to be a \_\_\_\_\_”

The poster will present detailed cases following the teachers from the research lab to their classrooms, connecting teachers’ beliefs to changes in student understanding of STEM practices.

## Connection to Conference Theme

This on-going work is strongly connected to the conference theme, *Learning and Becoming in Practice*. Preliminary findings suggest that teachers—even with no prior experience in engineering—can learn by being placed in an engineering lab. By temporarily becoming engineering lab members, they developed stronger identities as teachers who can engage their students in STEM practices.

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## Acknowledgments

The authors would like to acknowledge funding for this research (NSF #EEC1301373).

# Contradictions on the Process of Becoming a Physics Teacher

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**Abstract:** Our objective is to focus on contradictions of the process of learning and becoming a physics teacher. We undertook this research at undergraduate course called "Practices on Physics Teacher" addressed to third-year pre-services teachers. Data were gathered by recording classes and interviewing students. Using cultural-historical theoretical and analytical framework, we will point out macro and micro-levels contradictions of becoming a physics teacher.

## Introduction

Physics Teacher Education in Brazil has been taking part in research agenda on Science Education for many years (Villani et al, 2009). However, it does not mean all themes have been investigated. Considering that, in this paper we present findings from a study conducted with the purpose to investigate Physics Teacher Education Program (PTEP) in which undergraduate students had to take their practicum in a High School. Using Cultural-Historical Activity Theory (CHAT), we will reveal some contradictions present on the process of learning and becoming physics teacher. Based on Engeström (1987)'s ideas we will point out two set of contradictions: (i) those present on macro-structure of activity; (ii) those present on micro-structure which are revealed by subjects' actions and speech.

## Methodological Protocols

Our research is undertaken in course entitled *Practices on Physics Teaching* addressed to third-year undergraduate physics students (pre-service physics teachers) at a Brazilian public university. Events of lessons,- in which students and the professor gathered every fifteen days to discuss different sorts of topics in physics education,- and interviews were taken as our object of research.

Based on the qualitative methods we collected our data by videotaping classes at university, in which 75 people were involved and 70 hours of video were recorded. In the end of academic year, we interviewed 10 of those students (who accepted our invitation). Interviews followed a semi-structured protocol wherein questions were about: reasons of choosing a Physics (PTEP), their perceptions about how teachers should be educated, (early) teaching experience, solving problems during the practicum. Analysis is oriented event-based (TOBIN & RITCHIE, 2012), that is, we select events happened on the classes in which contradictions come out in order to understand what was going on at that moment.

## Theoretical Framework

This research (design, methods and analysis) draws on the Cultural-Historical Activity Theory (CHAT) whose foundation emerged from Vygotsky's idea who argued the relationship between the subject and object is always mediated by instruments. Stating that Vygotsky "maintained the human beings are agents who react to and act upon mediating objects of the environment such as tools, signs, and instruments leading to an outcome" (Nussbaumer, 2009). Other elements were added to Vygotsky's idea by Leontiev (2009) such as the motive that orients the activity and conducts the guided action and automatic operations. Over the past two decades, Engeström (1987) proposed a complementation of these ideas when he introduced the community, rules and values, and division of labor as part of the human activity structure. These elements are underneath by either mediating the relation between subject and object or "reciprocally influence the achievement of the object and the final outcome" (Nussbaumer, 2009).

The arousal of *inner contradictions* is the consequence of this set of mediations within a complex human activity. For instance, Roth & Lee (2007, p. 203) say "activity systems harbor *inner* contradictions, which come with the coexistence of mutually exclusive elements". They also state "when inner contradictions are conscious, they become the primary driving forces that bring about change and development within and between activity systems. Generally overlooked is the fact that contradictions have to be historically accumulated inner contradictions, within the things themselves rather than more surface expressions of tensions, problems, conflicts, and breakdowns".

In this same perspective Engeström (1987)'s ideas of inner contradiction of human activity points out the cultural-historical aspect. He quoted "the basic internal contradiction of human activity is its *dual existence* as the total societal production *and* as one specific production among many. This means that any specific production must at the same be *independent of and subordinated to* the total societal production (...). Within the structure of any specific productive activity, the contradiction is renewed as the clash between *individual actions and the total activity system*." (p.52).

## **Discussions and Findings**

These set of contradictions are related to the historical perspective of the activity system. According to Egenström (2001), "contradictions are not the same as problems or conflicts. Contradictions are historically accumulating structural tensions within and between activity systems". Considering that, for this paper we carried out our analysis by selecting events and characterizing them as our data in two general set of contradictions. From the video analysis, but mainly the interview, we are able to distinguish contradictions in two different levels, macro and micro, which are going to be defined in the following.

### **Contradictions at Macro-Levels**

Therefore within Teacher Education activity system macro-level contradictions are: (i) attending to Physics Teaching Program does not mean to be a teacher; (ii) the locus for educating, physics department or school of education; (iii) theory and practice; (iv) conflicts between scientific carrier and teachership. For instance, we present below a fragment of one pre-service teacher's interview, in which he speaks about his choices so that is possible to highlight contradictions (i) and (iv):

**Researcher:** Tell me a little bit about your choices, I mean why did you choose a Physics Teacher Education Program? Have you always meant it?

**Moises:** Actually, in the very beginning I didn't want to pick this carrier [PTEP] I even didn't know what this carrier was as the majority of people who gets in here. I wanted engineering instead, mainly because of status of being an engineer or earning a good salary. (...) I realized my scores wouldn't be enough to apply to engineering so I thought what am I gonna do? I wondered to apply to maths and I did it, but I failed. Then I start wondering to apply to physics, but I didn't want to PTEP. I'd like to get in the scientific carrier. So I ended up in PTEP because of my scores, I mean I was afraid of not having enough and applied to PTEP.

### **Contradictions at Micro-Level: "I Don't Know to Be a Constructivist Teacher. I Guess I Will Be a Traditionalist One"**

This is Igor's quote, one of pre-service teachers. By the time he exclaimed it, he had been asked to sketch a planning class about electromagnetism. It means he was working on a kind subject-matter should be taught at High School physics lessons and which strategies would be better to employ. Igor was involved in small group discussion and they struggled to figure out how to do that task. Following is Igor's transcription

**Igor:** I don't know how to be a constructivist teacher!

**Student 2:** such as Paulo Freire, Piaget?

**Igor:** Nop! I don't think Piaget is that constructivist ... and I don't know how to teach with Paulo Freire, but I know to do it in a class like STS. Do you know what is it? [he asks to student 2] Science, Technology and Society ... I think I am more, you know, traditionalist although.

The contradiction present in the Igor's quote is about being *and* not being, it means, mutually exclusive aspects of activity. Also, Igor reveals in his practice the contradictions "between *individual actions and the total system*" (Engeström, 1987, p. 52). In the other words, being either constructivist or traditionalist is his individual action so that to pursue one or another he has to follow specific rules. Rules are a socio-historic (collective) construction which makes subjects to belong to a specific group (of those who are constructivist or traditionalist, for instance). On the other hands, rules are related to the totality of the system. Then ways of (not) being is related to ways of belonging and so does to ways of becoming. We think these triple kinds of ways are what support human beings' practice. Hence Igor's case highlights exactly the micro-level contradictions. As a result a subject learns and becomes (a physics teacher) in a practice in which those layers (macro and micro) of activity are integrated to each other and in which contradictions come out.

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# Women Becoming Engineers

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**Abstract:** In this paper, I present a case study of a student becoming an engineer to highlight the ways in which women become engineers. Drawing on theories of situated learning and feminism in engineering education, I analyze the gendered practices of engineering education. My analysis suggests that the construction of gender in engineering education has implications for how engineering learning occurs, resulting in implications for both engineering education and learning theory more broadly.

## Introduction

In a recent article in the Journal of Engineering Education, Johri and Olds, along with multiple contributors from the learning sciences, argue that the research communities of engineering education and learning sciences can both benefit by their mutual engagement and collaborative research (2011). The authors argue that the theory of situated learning in particular is gaining prominence in both fields and is a promising theoretical lens to approach studies of learning in engineering. The research presented in this paper is the result of this type of collaboration between learning scientists and engineering educators. This work comes out of a broader, ongoing ethnographic study called Cognitive Ethnographies of Engineering Design in which engineering educators and learning scientists are investigating engineering design practices in both undergraduate courses and workplaces. My individual focus, however, is on women becoming engineers through their undergraduate coursework.

According to the NSF (2013), women represent less than 18% of all engineering enrollments. Much of the research to date on women in engineering focuses on quantitative measures of women's success and/or persistence in the field (Beddoes and Borrego, 2011). My research focuses on *how* women are succeeding and/or persisting. The goal of my research is to uncover how undergraduate classroom practices, and institutional structures and policies, enable and/or constrain women's success in undergraduate engineering: or more succinctly, how women are learning to be engineers. This work has implications for the ways in which gender is taken up in learning theory, and has the potential to inform ways in which women's success can be increased in engineering.

## Conceptual Framework

To investigate women becoming engineers I draw from theories of situated learning and feminism in engineering education. Both theories focus on the individual in context. While situated learning has explanatory power regarding the ways individuals navigate pathways and trajectories, feminism highlights how these pathways and trajectories are gendered.

## Situated versus Cognitive Theories of Engineering Learning

Situated learning takes learning to be a function of the activity, context, and culture in which it occurs; it is a fundamentally social phenomenon. This stands in opposition to cognitive approaches to learning in which learning is thought of as the acquisition of decontextualized concepts transferable to other situations at other times. In documenting how students become engineers, Stevens et al., (2008) demonstrate that persons are always and without exception, persons in context. The broader organizational practices individuals engage with influence the pathways in or out of a community and there are both official and unofficial routes to becoming an engineer. This results in some students pulled in and other students pushed out of the discipline.

## Interactional versus Liberal Feminism

The majority of research regarding women in engineering is implicitly based in a liberal feminist tradition (Beddoes & Borrego, 2011). Although valuable in its seeking of equality between men and women, liberal feminism is limited in that "woman" is seen as a homogenous category, often universalizing white, western, middle class women. Interactional feminism, on the other hand, is concerned with the ways gender is produced in the encounters and processes of every day. By focusing on discourse, interactional feminism rejects presumed binaries, and attempts to uncover gendered behaviors and interactions to produce new explanation as to how and why masculine biases persist in engineering.

## Methods

This study was conducted at a large, US public university. It is based on the analysis of observational data collected in two undergraduate engineering courses. This first course was a general engineering freshman design course with 30 students enrolled. The second course was a senior mechanical engineering design course with 100+ students enrolled. The freshman course met three times a week; the first session was a one-hour course lecture; the other two were two-hour working labs. The senior course met twice a week for one hour and fifteen

minutes. In addition to these courses, this study includes observations of the weekly planning meetings for instructors teaching freshman design, weekly staff meetings held by the instructor of senior design, and weekly team meetings from one senior design team. The data includes fieldnotes from over 100 hours of observation, as well as informal interviews with students, instructors, and teaching assistants in the design courses.

## A Case Study of Becoming an Engineer

Preliminary findings underway suggest that gender is made salient in undergraduate engineering education in ways that impact potential learning. Engineering classroom practices as well as institutional structures continue to prescribe gender norms resulting in fixed categories of expectation. In my poster, I will expand upon these practices and my analyses, but I offer the following vignette as a representation of my preliminary analysis.

*Vignette: Ares.* The engineering center is a collection of buildings, connected by a labyrinth of walkways so that you never have to go outside to get from one building to the next. There are computer labs, and machine shops dispersed throughout with some labs underground three floors. Signs are suspended from the ceilings directing you which way to go, and directing you to the women's restrooms. The women's restrooms were retrofitted from previous men's restrooms with the urinals left in tact. I navigate this maze to the freshman design classroom. Outside of the classroom are pictures of engineering projects for third-world countries under the caption "engineering with heart" only the heart was the symbol and not the word. It is in the freshman class that I first met Ares. Ares would often sit in the back or the corners of the classroom, slouched in a chair. With black pants and black shirt, Ares seemed invisible. Ares could pass for a twelve year-old boy; awkward and shy like many other freshmen. For the first few weeks of observations, I thought she was male. It wasn't until the class was split into their project teams that I realized she was biologically female. Instructors are strongly encouraged to pair females in group-work so that no one female is left with the secretarial tasks. After many observations and informal interviews, Ares gender remains ambiguous. She has told me that at times she binds her breasts to suppress her femininity, but likes her feminine eyeglasses. She plans on double majoring in aerospace engineering and French because she likes both the hard science aspect of engineering but enjoys communications. In more ways than one she defies categorization.

## Discussion

As this vignette suggests, gender is made visible in engineering education at every literal turn. The signage that points to the women's restrooms containing men's urinals serve as a reminder that as a woman you don't belong here, or at least you didn't at one time. The imagery on the wall of engineering with a heart is strategically placed outside of the freshman design classroom to entice female students into engineering by appealing to their sensitive emotions, one of the many practices that essentializes women's identities in engineering education. Ensuring that women are not lone participants on a team is another strategy designed to improve women's experience (Tonso, 1996), but when probed as to why, instructors often cite that is so women can *share* secretarial duties, not to prevent them from doing it in the first place. Women are categorized and then essentialized in engineering education. What, then, do we make of Ares? She is confronted with imagery and practices that remind her you can only be one gender, and she is placed on a team based on her sex, but can we say her experience is improved because of it? This remains to be seen and needs further investigation.

The learning sciences as a field continues to explore the connections between identity and learning, and yet, a salient feature of identity, gender, continues to be under-theorized. As Ares' case suggests, understanding gender and learning is complex, and we need to advance our learning theories to address this complexity.

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## Acknowledgments

All participants are listed with pseudonyms. This work was supported in part by NSF grant CMMI-1355599. The opinions in this paper are those of the author and not necessarily of the US National Science Foundation.

# Characterizing Teachers' Analysis of Student Work

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**Abstract:** We report on our analysis of teachers' investigation of student work on open-ended mathematics tasks and present an emerging framework for explaining the variety of ways teachers engage with and attempt to analyze and organize conversations about student work. This emerging framework will provide potential starting points for professional development focusing on student-centered instruction

While the importance of instruction that builds on student thinking and understanding has been advocated by both research and policy documents, this type of instruction is often challenging for teachers to design and enact (Sherin, 2002). We argue that before we can effectively support teachers' sustained focus on student thinking and understanding as part of their instruction, we must better understand their current views and practices with regard to the role of student thinking in instruction. Building on the teacher "noticing" research (Sherin, Jacobs, & Philipp, 2011), we explore 24 mathematics teachers' participation in investigation of student work on open-ended mathematical tasks. We report on our examination and present an emerging framework for explaining the variety of ways teachers engage with and attempt to analyze and organize conversations about student work.

## Theoretical Background

We follow Sherin et al. (2011), who note that analysis of student work is a key component of teaching expertise and can support teachers implementation of a variety of reform-oriented pedagogical practices. Instruction and feedback that is grounded in student thinking and understanding (i.e. using formative assessment) has been shown to significantly accelerate learning, when compared to students who receive traditional grades on assignments (William, 2011). Despite the importance of student thinking in instruction, mathematical noticing – "attending to particular events and making sense of events in an instructional setting" (Sherin et al., 2011, p. 5) – has only become a focus in mathematics education research in the past decade. While numerous recent have documented the importance of mathematical noticing and analyzing teachers' attempts to notice specific aspects of student thinking and classroom events and interactions, there is little known about the specifics of supporting teachers' ability to engage in productive mathematical noticing. Our current work is focused specifically on that issue and the proposed poster will explore a foundational question: *When tasked with engaging with student mathematical thinking, how do teachers interpret and enact that task?* We argue that any efforts to support teachers' productive mathematical noticing must be grounded in their current beliefs, understandings, and practices and the results of this study will increase our understanding in this area.

## Setting and Method

Data for this poster comes from a three-day professional development institute focused on supporting teachers' ability to collaboratively develop and use formative assessment. We report on 24 teachers who were tasked with individually reviewing, analyzing and describing student solutions and explanations to open ended problems and then discussing that analysis as in small groups. The task was purposefully left open to allow the teachers to use existing experiences to individually construct and then as a group co-construct the task. Participants' written notes from the individual analysis and video recordings of the group discussion that followed were the primary sources of data for the current study. Members of the research team reviewed the data corpus and theoretically significant excerpts of audio/video were identified and transcribed. These excerpts were coded by at least two members of the research team using an open coding system and common themes and patterns within and across the groups were identified and noted. These conjectures about common themes and patterns were reviewed chronologically against the entire data corpus and contradictory and corroboratory evidence were identified. Empirically verified characterizations of the ways in which teachers' interpret and enact tasks that focus on analyzing student thinking were the result of the iterative process of conjecturing, testing, and revision of conjectures.

## Analysis and Results

Three primary characterizations of the groups' activity with the student work emerged from our analysis: focus on instruction, focus on calculation, and focus on strategy. Below, we present an abbreviated analysis of two characterizations– focus on instruction and focus on calculation. In the proposed poster session, we will present detailed analysis of all three characterizations.

## **Focus on Instruction**

One common way of interpreting the role of student thinking was to focus on instruction. For example, members of the Green group described the task that they were assigned as focused on “identify[ing] the big ideas of what is going on with the student work.” While evidence and examples from the group’s analysis of student work served to anchor the conversations, the exchange led to discussions about their own instructional practices and/or struggles rather than the student work and underlying student interpretations. For example, Sam commented on how well Fran’s students explained their thinking and Fran described the instructions she gave her students:

Fran: “Make sure you write a story. I kept using the work story a lot. You know, you write a paper with a beginning, middle, end, and just support your ideas and your thinking because we can’t just tell. I don’t know if that’s reflected in what they do or not.”

Sam: Oh absolutely, if I had classes of kids that put out papers like this on a consistent level, I would be in heaven.

This group’s conversation quickly became decontextualized from the student work, however, the task itself seemed to provide an opportunity to discuss the teachers’ own practice. In particular, the importance of communication of mathematical ideas came up repeatedly (e.g. showing ones work, neat handwriting, identifying key variables, etc.). It is worth noting that this group neither solved nor discussed the mathematics of the problem nor did they look closely at the actual student work to unpack the mathematical thinking.

## **Focus on Calculation**

Rather than collaboratively defining the task, “calculation” groups just dove into it. For example, the indigo group focused on a close analysis of one student’s work and sought to understand what the student did by collectively piecing together their selections and discussing questions they had about the student’s work. For example, consider the following extract:

Leila: What first intrigued me about this...was the box because the first time, I thought they were going to factor it and then I realized they were multiplying out that way...but didn’t finish it. It’s like they gave up when they had to multiply...-29 by -20.

Linda: Well, they didn’t finish it up in the box, but they actually wrote it down at the bottom. So the  $x^3$  minus...is still in the box.

Blake: I noticed that they were using variables and I was trying to infer what they were letting their variables represent, so I thought that they were saying  $x$  was equal to the number of students and then  $k$  was the dollar amount that each would pay, so like cost per student, I guess, or admission per student.

Leila: Which they set up a great equation.

The group worked collaboratively to make sense of what the student did – step by step – and where on the paper he did it. However, their analysis is very “surface level,” focusing only on being able to describe and narrate the solution path this student chose to pursue, much like how a student would describe the steps he or she took presenting a solution to the class.

## **Discussion**

In this poster, we will describe three characterizations of the way teachers interpret and co-construct the presented task (focusing on instruction, focusing on a calculations, and focusing on strategy). These characterizations provide potential starting points for professional development focusing on student-centered instruction; without recognizing the various understandings and interpretations various teachers bring to professional development, it is likely that teachers will not interpret instructions in the way they are intended. Further, it is likely that teachers with different interpretations may encounter communication challenges and have difficulty successfully completing the task, engaging in productive argumentation, or coming to consensus.

In addition to presenting the characterizations, we will also present a preliminary version of custom-designed software that will scaffold productive mathematical noticing and provide opportunities to surface teachers’ current beliefs, understandings, and practices with regards to the role of student thinking in instruction and make them explicit topics of conversation.

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# Beyond Databases: Librarians in a Project-Based Language Arts Curriculum

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**Abstract:** This study examines how librarians were positioned and their expertise leveraged in high school classrooms enacting a project-based ninth grade English Language Arts curriculum crafted from design-based research. Using a sociocultural lens, a qualitative analysis of the data reveals that in most situations the librarians' lack of embeddedness in the school and students' lives positioned them as outsiders and diminished their effectiveness in scaffolding students in the research process.

## The Major Issue(s) Addressed

Effective learning requires access to people and resources that represent experience and knowledge in the field of study (Barron, 2006; Bell, Tzou, Bricker, & Baines, 2012; Lave & Wenger, 1991). To support students in developing the skills required for completing research papers, librarians are often asked to provide their expertise as information professionals. A skilled librarian does more than provide books, but also mentors individuals throughout the research process, from task definition to evaluating the final product. Each student comes with a personal history of information seeking and use that needs to be recognized and incorporated into the instructional scaffolding. In order for a librarian to develop useful instruction, they need to know both where students are coming from and where they are going, having a vision of the curricular goals. These purposes are best met by having a librarian embedded in the school setting. (Dresang, 2013)

Despite librarians' value as information experts, many schools no longer employ a full-time trained librarian as a member of their staff. In order to meet the need for expert advice on the research process, a teacher may turn to local public librarians, particularly those whose work focuses on youth. While these public librarians are also information professionals, they are not embedded within the life of the school and, more particularly, the lives of these students. Additionally, they may not have knowledge of the curriculum and will likely only talk to the students a handful of times. In such a situation, it is unlikely that the public librarian's expertise will be fully utilized, given their limit connection to the students and their needs. Yet since many teachers and librarians across the country engage in this manner, it is important to explore the facets of this situation.

Therefore, this research poster explores two questions: 1) how are librarians' expertise leveraged in a school setting? and 2) how are librarians' positioned in a project-based English Language Arts curriculum? The data comes from a two-year designed based research project to create a 9<sup>th</sup> grade English Language Arts curriculum that is project-based and offers opportunity for interaction with experts. Analysis reveals the affordances and constraints within the school setting for leveraging librarian expertise.

## Potential Significance of the Work

This work is potentially significant in two ways. First, it examines how adult expertise functions in the classroom. Second, it considers how librarians, who are often called into classrooms, are positioned within a curriculum. For many decades K-12 educators have sought ways to connect their students with "real-life experts" in their community. Librarians are a part of most educational communities, whether as a full-time member of the school staff and/or a trusted resource within the realm of student lives. Yet little existent literature in library sciences and none in learning sciences examine the role of these adult mentors in the learning of youth.

## The Theoretical and Methodological Approach(es) Pursued

The author examines this research from a sociocultural viewpoint, considering the practices enacted in the situation. Particular attention is paid to the how librarians function as part of the students ecologies of learning (Barron, 2006) and how librarians were positioned within the curriculum (Wortham, 2006). Qualitative content analysis was conducted on video recordings of public librarians presenting in a classroom, survey data of student opinions about these presentations, and librarians' expert feedback on student work during the first year. From the second year, the author analyzed interviews with a school librarian and field notes from conversations with enactment year teachers. Initial themes were identified in consultation with experts from the research team, after which the author analyzed the data corpus for additional themes.

## Preliminary Findings, Conclusions, and Implications

During the first year enactment of the curriculum, public librarians were asked to participate in a unit on current controversies and argumentation writing. The purpose was to have these librarians share their expertise in seeking credible information on current events as well as other parts of the research process. Yet because the public librarians were not embedded in the life of the school, their knowledge of the students and the curriculum was limited. Additionally, the teachers positioned the librarians as outsiders in how they spoke with and about them. When the librarians came to share their expertise in class, it was in the form of a presentation that did not draw on the students' knowledge of information seeking nor demonstrate the depth of knowledge and resources that the librarians could offer. Many students had seen similar presentations before and quickly became disengaged in the activities meant to assist them, later complaining about the librarians' visit. Later in the unit, the librarians participated in a potentially more effective activity by reviewing individual students' potential references for the argument paper and offering advice. Here the librarians were better able to assess the individual students needs and scaffold their suggestions to maximize learning. Unfortunately, because of the students' frustration with previous interactions, most did not take the librarian's feedback seriously.

During the second year enactment, teachers of the curriculum at multiple locations were invited to use their local school and/or public librarians to participate in the current controversies and argumentation unit. Such a simple request proved complicated by the various administrative and political structures in different schools and towns. For example, in one situation the teacher worked as part of a special program that was being housed in another school building, and felt they could not access the school library. In another town, there was no school librarian and the nearest public library was a town away. In contrast, one of the high schools had a librarian working full-time on staff that had made an effort to become embedded in the life of the school. This librarian understood the curriculum and maintained positive relations with the teachers. Positioned as a reliable resource to the students, she was able to assess and respond to students in the controversies unit as well as later units. She observed changes in the students patterns of inquiry in the library and found they asked more sophisticated questions as they participated in the units and she was able to work with them repeatedly over time.

Based on these initial findings, the implications are that librarians have the potential to be valuable partners in student learning if their expertise is leveraged properly. Librarians, whether on the inside or the outside of the school, need to be positioned as the experts they are by teachers and students. They also need to understand the curriculum and find ways to build on students' knowledge, not assume what they need to be told, such as repeating a stale presentation about databases.

## Relevance to the Theme of the Conference.

This study is about learning and becoming in practice, in that we sometimes learn or become something unintentional when theory meets practice. In theory, as the curriculum was designed, utilizing the expertise of school and public librarians seemed logical and relatively easy to accomplish. In practice, the affordances and constraints of the school settings and the practices of the participants lead to librarians positioned as uninformed outsiders and students learning that these information professionals aren't able to assist them in achieving goals. While many schools had difficult situations with their librarians, the example of the well-embedded high school librarian provides hope that students, and teachers, can learn a different lesson.

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## Acknowledgments

The author gratefully acknowledges the contributions of fellow researchers Paul Teske, Annie Kuo, and Déana Scipio as well as the work of the University of Washington Institute for Science and Mathematics Education and Educurious Partners.

# Characterizing Teachers' Support of Modeling Practices in Science Classrooms

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**Abstract:** Modeling used, as an inquiry tool is critical to the development of understandings in science. Teacher knowledge of this use of models impacts their development of learning experiences for students. This study focuses on teacher modeling practices and relates them to student performance on assessment items requiring interpretations of multiple representations. This characterization of teacher practices will provide insight into the learning experiences needed for students to engage in authentic scientific modeling.

The practice of building, refining and redesigning models based on evidence lies at the core of scientific practice. It drives scientific discoveries as scientists use models to guide experimental design, test variables, and generate hypotheses. (Windschitl, 2006) According to the *Framework for K-12 Science Education* (NRC, 2012) and the *College Board Standards for Success in College* (CB, 2009) these ideas play a critical role in the development of scientific ideas and understanding in students. While in the classroom, models are traditionally used by teachers to present “correct” information to students, the power of modeling as a tool for inquiry and exploration is not often employed. (Justi, 2002)

In order to foster the scientific practice of modeling in students we must better understand how teachers currently use modeling in the classroom. In this study, we will be to characterize teacher practice with regard to modeling and explore the relationship to student performance on science assessment items that require modeling skills including the interpretation, evaluation and critique of models and representations.

## Framework

Developing a learning environment that supports students in creating and using models requires a complex set of knowledge and skills. Teachers make instructional decisions based on their pedagogical content knowledge (PCK). When teachers lack sufficient knowledge about scientific modeling they are unable to make the type of instructional decisions necessary to support students’ understanding. In the classroom, the educative power of models and modeling is commonly underestimated. Traditionally, the teacher uses models to present information to students. For example, in their study of the beliefs of experienced secondary science teachers, van Driel and Verloop (2002) found that many teachers generally focused only on the descriptive function of models and ignored the predictive power of models and the use of modeling as a scientific practice.

Teachers’ orientation toward teaching science can also influence their instructional choices around modeling. This orientation reflects the pedagogical knowledge teachers’ use to manage and organize classroom activities. These general principles are another important aspect of PCK (Shulman, 1986). van Driel and Verloop (2002) found some teachers chose a teacher directed approach using models as a tool to focus on the content. Other teachers used a more constructivist approach, encouraging students to design and build models to form explanations. The latter is more consistent with by the national standards (NRC, 2012; CB, 2009).

## Methods

This study is a part of a larger project focused on measuring students’ progress along a hypothetical learning progression related to transformations in matter. Our study included 13 middle school science teachers from 5 different schools. The schools included public, private and charter schools in urban and suburban settings. The approximately 1600 students varied in race, ethnicity, and SES (15%-52% free and reduced lunch).

Students from each school were tested at the beginning (Fall 2010) and end (Spring 2011) of the school year. We estimated students’ latent ability parameter based on item response theory (IRT, Wilson, 2005) analysis and calculated the change in student mean ability levels for each teacher. For this study we also compared students’ gains on items that required students to use modeling skills with disciplinary knowledge.

Data related to individual teacher enactment was collected through classroom observations and surveys. We electronically collected surveys from teachers using Survey Monkey. Survey questions related to teachers’ backgrounds and their teaching practices, which included use of modeling and inquiry strategies. We conducted multiple classroom observations to characterize teacher practice and the instructional experiences of students. We used an ethnographic approach that focused on creating detailed descriptions of classroom activities using a running record. Running records were coded using a coding matrix that focused on types and

purposes of modeling activities in the classroom (Peek-Brown, 2013). For inter-rater reliability, two team members independently scored at least 10% of the data and reached 90% or greater agreement with 100% agreement after discussion.

## Results and Discussion

In order to characterize teacher practices that might be related to student performance on assessment items related to modeling preliminary analysis of data was limited to two teachers (Creed and Dorsey) from the same school that teach the same grade. Their curriculum materials emphasize engaging students in the practice of modeling and support students in relating observed phenomena to the unseen processes that occur at the molecular level (development of a particulate model of matter).

Despite similarities in population and curriculum materials, differences in student performance were observed. Dorsey's students performed better on more complex items that require applying disciplinary knowledge and interpreting, evaluating or critiquing representations. For five of eight items focusing on interpreting molecular level representations, Dorsey's students performed better than Creed's students.

Preliminary analysis of teacher data provides insight into the source of the observed differences in student performance. In the survey Dorsey reported regularly using modeling strategies during instruction, while Creed reported rarely using modeling even though modeling practices are an integral part of the curriculum.

Observational data was consistent with the survey data. Dorsey had 19% more instances of modeling-related activities than Creed. The majority of observed modeling activities in Creed's class were student driven (88% of coded references). A more balanced approach was observed in Dorsey's class with 46% of the coded references being teacher driven, 38% student driven and 16% collaborations between the teacher and students. Although these results would seem to indicate that Creed's students spent more time engaged in actively building their own models, a closer look at their modeling experiences suggests differently. For example, both classes were observed engaging in a modeling activity where students built molecules from gumdrops. Both teachers used the same lessons from the curriculum however the focus of their lessons was very different. Creed gave students directions as to how to build their models, but gave very little explanation as to why they were building them. In contrast, Dorsey engaged students in relating the model and the actual object in order to help students understand the limitations and the purpose of building different models.

Although both teachers participated in identical professional development activities around these lessons Creed did not seem to recognize the development of modeling skills as an important aspect of the lesson. This lack of understanding may have contributed to the instructional decisions that she made. Further supporting data from student assessments and data for other teachers in the study will be included in the poster.

## Implications

As the field moves toward the goal of supporting students in coherently developing understanding of core science concepts blended with scientific practices, learning research is needed to gain insight into how to effectively support teachers in meeting these goals. By characterizing teachers' practice related to modeling and linking it to student progress along a learning progression performance, this study contributes to that effort.

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## Acknowledgments

This work was funded by the National Science Foundation (grant number 0822038). Any opinions expressed in this work are those of the authors and do not necessarily represent those of the funding agency.

# **Advancing Epistemological Frame Analysis to Refine Our Understanding of Inquiry Frames in Early Elementary Interviews**

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**Abstract:** The present study contributes to our understanding, and the methods for measuring, students' epistemological framing in the context of thirty first- and second-graders learning about complex systems. Our goal was to automate the process of identifying frames by coding behaviors and then determining whether they cluster around specific researcher identified frames. We developed a dual-layered coding scheme of the video recordings from semi-structured interviews and a Bayesian model to provide validity warrants to our analyses.

Research has shown that the way students interpret an activity such as a cognitive interview will shape how they will respond, explore, and learn within the activity (Russ, Lee, & Sherin, 2012). Of particular importance are the expectations that students develop for how they are to engage with knowledge in a given situation. These expectations, called "epistemological frames" (Scherr & Hammer, 2009) have, for example, been shown to influence whether students who are asked about something they don't know will simply state that they don't know or actively attempt to explore and identify a valid answer. Traditionally, students' epistemologies are measured through self-report, and as a result do not always provide accurate information about their epistemological stance as it relates to the contexts in which they are learning (Scherr & Hammer, 2009). Therefore, epistemological frame analysis has been developed to analyze this contextual dependency of students' expectations with respect to knowledge. This method studies the interaction between students' framing, behavior, and the content of their speech and has been used to describe the relationship between students' frames and the way they engage with learning activities at the middle school through college level.

In this paper we aim to build upon this work in two key ways. First, we will explore the association between students' framing, behaviors, and the substance of their thinking with early elementary students learning about complex systems concepts such as emergence (Jacobson & Wilensky, 2006), in the context of a semi-structured interview about bees collecting nectar (Danish, Saleh & Andrade-Lotero, 2014). Exploring the utility of frame analysis in this new context will provide insight into how to evaluate interview data with younger children, and any unique challenges that working with young children introduces will further refine the theory and practice of using frames to answer questions about student knowledge and learning. Second, we are attempting to refine the methodological toolkit used to identify frames in an effort to develop a more consistent measurement approach. Specifically, we explore the potential for using a Bayesian analysis to identify whether clusters of observable behaviors can be used to predict researcher-interpreted frames in rich video data of student interviews.

## **Conceptual Framework**

Learning scientists have increasingly paid more attention to how students understand what kind of learning activity they think they are in (Greeno, 2009). For instance, researchers focus their attention on students' expectations of what knowledge, reasoning, and learning in a particular discipline entails (Hammer, Elby, Scherr, & Redish, 2005). Frames have been defined as a pragmatic meta-message of 'what is going on' in people's moment-by-moment interactions (Bateson, 1955). These context-based epistemic units organize our behaviors with respect to the way we interpret the world as well as other's behaviors. When students engage in a new activity, their prior expectations would guide their framing differently, and in such a way it may be more or less productive for the instructional goals of the learning activity (Hutchison & Hammer, 2010). In this particular study, we want to see how students' framing of the interview context influences their engagement with the content (complex systems concepts) being discussed. Specifically, building on Russ (Russ et al., 2012), we believe that an inquiry frame will involve students re-examining their assumptions and thus reaching new conclusions whereas an examination frame will lead to terse answers and little additional learning.

## **Research Design**

The analysis that follows is based on a secondary analysis of data collected in the spring of 2012 (Danish et al., 2014). Thirty first- and second-graders (6-7 years old) took part in this study. The purpose was to support students' learning of complex systems by scaffolding a computer simulation about bees with inquiry prompts. Individual semi-structured interviews were conducted as a post-test to obtain evidence for the students' level

of understanding of complex systems. During the interview, students were asked questions about the behavior of bees as a measure of direct learning. For instance, children saw the picture of a beehive and a flower with nectar and explained what they thought the bees would do. Video recordings were obtained from both the intervention and the interview. In the present study we focused our analysis on the video-recordings of the interviews. We divided each video excerpt in a sequence of 10sec segments. We consider a 10sec segment long enough to include sufficient information about the behavior, yet short enough to provide sufficient discrete data points for our statistical analysis.

Prior examinations of students' frames have involved having multiple researchers code all of the student behaviors and then attempt to interpret students' frames through repeated watching of the video data. Our goal was to extend this approach in a manner that would more consistently map easily observed behaviors to frames, and potentially find shifts in frame at a finer-grained level of detail while adding the ability to report the statistical validity of the approach. Generally speaking, our approach involves using a subset of researcher-identified frames to establish a statistical model for which behaviors identify which frame, and then to vet whether we can use the behaviors to predict frames and frame transitions in the remainder of the data corpus. Therefore, we developed what we called a dual-layered coding scheme. The first layer comprises a series of lines of codes, one per observable feature. Grounding our codes on Russ et al. (2012) study, we coded five different features: a) body leaning, b) gaze, c) hand gesturing, d) hedging, e) volume and clarity of speech. For the second layer, we coded 25% of the video to identify researchers' interpretation of how students were framing the activity. We regard this interpretative set of codes as the 'training' set, from which the proportion and particular combination of observable features provide the basis for the automatized coding for the rest of the video. The algorithm employed was a Bayesian multilevel multinomial logistic regression to account for the nested structure of the data. We propose that discrepancies between interpreted and predicted clusters would provide empirical validity evidence for the inferences we make about students' epistemological framing. We also include evidence of external relations between our data and performance measures of student presentation of complex systems concepts on the interview questions.

## Findings and Conclusions

Our results indicate that we were able to use body, gaze, hand gesture, hedging behaviors, volume and clarity of speech to make predictions about whether students were engaging in specific frames as defined by Russ et al. (2012). This project aims to extend prior approaches to the analysis of epistemological framing and further refine our understanding of inquiry frames during interviews. Results can support researchers in intentionally designing to support those frames, such as inquiry, which support children's active exploration for answers. Our approach to using statistical models also provides new ways to include validity warrants in researchers' selection of observable features which guide their interpretations, and to increase reliability of characterizing students' frames.

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## Acknowledgments

We are grateful to Ginette Delandshere for her help in sharpening our ideas and to Asmalina Saleh for collaborating with us on the design and implementation of this study.

# Capturing Qualities of Mathematical Talk via ‘Coding And Counting’

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**Abstract:** We report on findings generated by a new method of quantified discourse analysis aimed at capturing qualities of mathematical talk according to Sfard’s (2008) “communicational framework”. The method is inspired by Systemic Functional Linguistic system of ‘Transitivity’. Findings revealed significant differences between two instructors’ mathematical talk in a teachers’ college course. These differences were mainly seen in the amount of ‘objectified’ vs. ‘personified’ talk of each of the instructors.

## Introduction

Methods for analyzing classroom discourse have proliferated in recent years together with the surge of interest in promoting ‘discourse rich’ instruction (Mercer, 2010). And yet, these methods are mainly concerned with what may be termed the ‘social’ rather than disciplinary aspects of talk. As useful as these methods are, they have difficulty in capturing aspects of the *content* of talk rooted in disciplinary practices. As such, important aspects of talk such as the level of abstractness or conceptual depth of the talk have not received as much attention as needed.

We suggest a new method for quantitative analysis of *mathematical* talk which is based on a ‘communicational’ framework for analyzing mathematical discourse (Sfard, 2008). Sfard conceptualizes mathematical learning as change in participation in a certain type of discourse. She distinguishes between ‘objectified’ talk and ‘syntactic talk’ which treats the mathematical signs without relating to the objects that are signified by them. Most often, this syntactic talk is accompanied by personified talk where the student talks about what they *do* to the mathematical signifiers, how they move them around, etc. The difference between personified talk and objectified talk has been captured by many others as the difference between “procedural” or “calculational” vs. “conceptual” talk (Rittle-Johnson & Alibali, 1999). Our goal in this work was to come up with a ‘coding and counting’ method that would capture quantitatively the difference between personified and objectified talk.

## Methodology

The data was taken from a larger project that aims at making explicit teaching and learning processes of prospective elementary school mathematics teachers in a college for education in Israel. For this purpose two similar courses were video-taped and fully transcribed. For the current analysis, two segments, similar in their mathematical content, were taken from the 6th and 7th lesson of each course (out of 14 lessons, 90 min. long).

The ‘objectified’ vs. ‘personified’ distinction was captured by SFL’s system of ‘Transitivity’ (Eggins, 2004, p. 207). Three types of categories were found to be most relevant: (a) Material: clauses that include an Actor and a Goal. We distinguished between material processes in which the Actor is human (ex. *You multiplied the two numbers*) from processes where the Actor is the mathematical object itself (ex. *the x moves up by 1*). The objectified quality of talk has been associated by Sfard (2008) with ‘being’ verbs. According to SFL, there are two main types of being processes: *Existential* processes, where things are simply stated to exist; and *Relational* processes, where things are stated to exist in relation to other things (are assigned attributes or identities). Thus, our next two categories are: (b) Existential processes that posit that ‘there was/is something’ (ex. ‘There is a linear function’). (c) Relational processes include (c1) Intensive attributive processes, in which an attribute is assigned to a participant (ex. ‘The slope **is** steeper’) and (c2) Intensive identifying processes, which are about *defining* (ex. ‘Intercept **equals** negative five’).

When looked at from a mathematical-communicational perspective, intensive:identifying, intensive:attributive and existential clauses may be indicators of a general ‘objectified’ quality of the talk, so long as the subject of the clause (Token or Carrier) are mathematical objects. In contrast, process:material clauses may indicate personified talk, so long as they include a human agent as the Actor of the clause.

We checked the reliability of our coding in three phases. After resolving disagreements, an agreed upon ‘clean’ version of the clause segmentation was prepared for further coding. The three phases were: 1. Reliability of clause segmentation (85% agreement). 2. Reliability of selection-for-coding: 89% (Kappa 0.76). 3. Reliability of clause-codes (according to the 5 categories described above) 100% (Kappa:1.0 ).

## Findings

Findings pointed to significant differences in the two instructors’ talk. Whereas Instructor 1 talked about

mathematical objects mostly in a personified way (24%) or by giving the mathematical objects some agency (41%), Instructor 2 used mostly Intensive Identifying and Intensive attributive clauses. Thus 72% of instructor2 clauses could be considered as ‘objectified’ while only 35% of instructor1 clauses could be considered as such. A chi-test revealed this difference to be highly significant ( $p < 0.001$ ).

Following is a very short example of the two instructors’ talk that we coded and compared. Both excerpts deal with the definition of ‘slope’ of a linear function.

Spkr	What is said (clauses delineated by [a],[b], etc.)	Coding
Inst.1	[a] ‘cause what is slope? [b] Again, what is slope? [c] How do you say that [d] this equals three? ( <i>points to the segment where the slope is 3</i> ) [e] For one unit [f] that we move on the x axis, [g] by how much did the y value increase? For the same unit.	[a]II [b]II [c]HP [d]II [f]HP [g]OP

In contrast, Instructor 2’s definition of ‘slope’ was very different:

Inst.2	[a] To determine, to determine whether [b] the slope is bigger or smaller, [c] then it is possible to look at the angle between the x-axis, [d] or some line parallel to the x-axis, ok? [e] And each of those graphs. [f] And it is possible to look at, [g] as we spoke last time, [f]the size of the step. [h]Now, note that [i]to determine [j] bigger or smaller [k] both ways are fine.	[a]HP [b]IA [c,d,e,f,i]HP [j,k] IA
<i>A discussion revolves around what “a step” is after which Inst. 2 summarizes her definition of slope:</i>		
Inst.2	[a] The height of the step when [b] the step's width is one unit. [c] That is, it is the change in the function's value when [d] the x value changes by one unit.	[a]II [b]II [c]II [d]OP

The qualitative analysis of the episodes from which these excerpts were taken revealed that through their talk, the two instructors made different realizations of the concept of slope available for their students. While instructor1 directed her students to realize “slope” only as a result of one type of routine (counting the difference in y values over one step of x), instructor2 elicited several different routines and thus made different realizations of slope (as an angle; as a “step” or quotient of dy and dx) available to her students. We believe the quantitative analysis partially captured this qualitative difference by showing that instructor 2’s talk was much more objectified than that of instructor 1.

## Discussion and Conclusions

We believe that the presented method, and especially its application together with qualitative methods of analysis, holds much promise. In recent decades, significant advancements have been made in understanding processes of teaching and learning mathematics via employing methods of discourse analysis (Ryve, 2011). Yet the potential of the findings from these studies to be generalized has been seriously limited by the qualitative and episodic nature of these methods. The present method is intended to extend the power of discourse analytical methods, and in particular, Sfard’s (2008) communicational framework, to enable comparison between teachers, classrooms and students. Such comparisons should provide us, in the future, with means to address important questions such as the relationship between the quality of teachers’ talk and students’ achievements.

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## Acknowledgments

This study is supported by the Israel Science Foundation, no. 446/10.

# Kinecting in Physics: Student Conceptualization of Motion Through Visualization

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**Abstract:** The purpose of this study is to share findings associated with using a Kinect® to generate large-scale visualization that served as a mechanism for student learning of physics. We explored the development of student comprehension of motion and examined the development of students' communication of these concepts to others. We examined the affordances of Kinect® in pedagogical practices, looking at how the hardware can be used to better scaffold student learning of physics.

## The Major Issue

Secondary students often have ideas about science concepts that are disconnected. One way to overcome these conceptual challenges is through the use of computer games and simulations that have the capability of immersing students in the study of unfamiliar scientific concepts (e.g. NRC 2011). Students often play virtual games and, through their play, develop tacit understandings of topics such as velocity and acceleration. However, gaming practices are not designed to provide opportunities for student articulation of Newtonian Physics or to extend the ideas that emerge. Though this is a challenge, research suggests (e.g. Masson et al. 2011) that the scaffolding of games and simulations can be used to support learning (Gee 2008). These simulations also have the potential to support students in integrating instructed knowledge with their tacit conceptual knowledge (NRC 2011), when the specific design of a simulation allows students to make choices that affects the models or visual images that are being generated. By using visualizations students can begin to integrate discrete ideas, allowing them to begin to make connections (Linn & Eylon, 2006) with complex scientific content that is represented through observable, unwritten representations. Studies, (e.g. Bereiter & Scardamalia, 2010) demonstrate that when instruction includes the students' co-construction of knowledge, students feel empowered to take ownership of their learning. The Xbox Kinect represents a new type of digital tool that can potentially strengthen these social interactions and embodied experiences in physics classrooms (Tolentino et al., 2009). One way in which this can occur is through the representation of dynamic processes at multiple spatial resolutions (Tolentino et al., 2009). By using the Kinect, students can move between multiple levels of abstraction (Megowan, 2007). This study examined the use of 3D simulation to support the teaching of Newton's Laws of Motion in a secondary physics classroom. Recognizing the affordances of embodiment and spatial resolution of this technology, our study aimed to identifying factors that allow Kinect simulations to increase student participation while simultaneously challenging them in their conceptualization of science content. Specifically: *How can the Xbox Kinect be used in pedagogically valuable ways to scaffold instruction in Newtonian physics?*

## Context, Methods and Analysis

Using a design based research methodology (Brown, 1992), this study has completed two iterative cycles. These were conducted at rural schools located in the Southeastern United States. Participants included secondary students in a physical science class ( $n= 24$ ). During each cycle, students were engaged in a unit on kinematics with a specific focus on displacement, velocity, and acceleration. As part of the designed implementation for each iteration, the students received instruction that included a series of stations with inquiry based learning. Each station allowed students to explore specific concepts related to kinematics. These activities encouraged student learning in two ways: 1) understanding of basic concepts associated with kinematics and 2) the transfer of conceptual understanding from one context to another. In addition to these stations, the experimental groups had an additional station that involved using the Kinect. Student transfer of conceptual understanding was then challenged through the use of large-scale visualization and communication to their peers of ideas associated with kinematics. During the first iterative cycle, data was collected from three primary sources: visual data using the Kinect, classroom observations, and interviews with the students. In the second iterative cycle, data was collected from four sources: a kinematic assessment, visual data (both traditional and Kinect generated), observations, and student interviews. The quantitative data was analyzed using descriptive statistics only because of a small sample size. The qualitative data collected to date has been analyzed using naturalistic methods to examine how learning unfolded during the use of the Kinect in the classroom. Using the constant-comparative method (Glaser & Strauss, 1967), researchers generated assertions from the data, consulting field notes and interview data to search for supporting and disconfirming evidence.

## Results

*Iterative Cycle I:* Observations of activity with the Kinect revealed that students had basic understandings of kinematics with one and two objects. Though comprehension was present, interviews revealed that the graphs being generated during the exercise resulted in some confusion. For example, when plotting acceleration, the Kinect® registered acceleration of the body movement. Because the visualization extrapolated information from multiple data points, the students had difficulty unpacking what was occurring. Their discourse also did not reflect that they were making sense of their observations. Instead of trying to understand the zig-zag lines generated by the multiple data points the students often stopped. For example, Brad, in the post interview stated the following: “*I was like, why is it doing this? It doesn’t look like a graph for velocity should.*”

*Iterative Cycle II:* Data and observations from this iterative cycle demonstrated that students have a preference for visual learning. In the interviews, one student noted, “*I feel that seeing is the best way to learn. I would like to see it and then learn it.*” This was a common theme throughout the interviews. Students made sense of their data through their comparisons of the Kinect data with graphs generated in the inquiry stations. The differences found in the graphing mechanisms seemed to contribute to students’ lack of conceptual understanding. This was supported by the quantitative findings that showed the experimental group scoring lower than the control group. This indicates that further scaffolding and support structures are needed in the next design cycle that will help students to work through the visualization and eliminate the potential misconceptions.

## Conclusions

The use of the Kinect® did generate large-scale visualizations and hands-on interactions that served as a mechanism for student learning, and an analysis of the data demonstrated rudimentary evidence of the development in student comprehension of motion. The students were also engaged in recursive activities associated with design-based learning and specific learning objectives, and, as a result of the structure of the activity, were beginning to develop a level of communication related to the concepts being taught.

The Kinect® presented numerous possibilities for learning, yet initial results have revealed that a high degree of scaffolding is still relevant to student success with conceptualization and communication of the data. We believed that the Kinect® afforded a number of opportunities for the development of knowledge construction. Yet, because of the challenges associated with presenting understandings that the students were not fully comfortable with, we did not see major advancements in student learning that we had hoped to see. However, we do believe that given the right scaffolding in the next iterative cycle, the Kinect® can be used as a way to encourage student learning by focusing on conceptual understanding through the use of content. The initial efforts of the students showed the beginning of this idea as the students were challenging their academic peers to solve problems in reverse, e.g. “*What does this image represent?*” or “*Can you emulate it?*” Where this activity fell short was that students’ were not asking their peers to make connections between established learning goals and what they were observing and doing. Though we have not yet established ideal use, we believe these findings will continue to refine the practices and implications of digital gaming and simulations, such as Kinect®, as an instructional tool for the development of student comprehension in kinematics

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# **“These are Facts”: Opportunities for and Barriers to Policy Changes that Support Learning**

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**Abstract:** Barriers to high quality learning experiences are often indirectly attributed to policy, such as mandated testing, yet learning scientists seldom engage the policy arena. This study presents early-stage design-based implementation research that aims to change policy. Interactions between legislators and a collaboratory constituted to investigate performance assessments are analyzed to better understand barriers and opportunities. We found differences along party lines that can be interpreted as barriers and constraints, suggesting directions for our ongoing work.

## **Issues Addressed**

Nationwide, in the United States, students take tests that are used to evaluate student progress, teacher effectiveness, and school quality; many test results are not useful in making instructional decisions and are controversial markers of learning and teacher effectiveness. To address this issue, a group of education leaders, teachers and university faculty formed a collaboratory. This group took their mission, vision, and research to the legislative education study committee (LESC) in hopes of launching policy change regarding opportunities for students to demonstrate mastery. Legislative perceptions of assessment practices and opportunities for learning are important to understand in order to make policy reform that creates opportunities for learning.

## **Significance**

Assessments currently measure basic skills and knowledge and tend to broaden and shallow the curriculum. These tests foster methods of instruction that make schools “a lousy place to learn anything in” (Becker, 1972). Prior work raised concerns about over-reliance on traditional forms of assessment because they can misrepresent what students know (Phillips, Gawel, Svihiha, Brown, Vye, & Bransford, 2009). Further, such methods have not been successful at narrowing achievement gaps or improving students’ opportunities to learn. Efforts to reform curriculum and instruction have been obstructed by the specter of high stakes testing. Performance assessments (PAs) allow students to demonstrate the complex practices and integrated understanding called for in new standards, such as Common Core. However, there are numerous barriers to adopting PAs in place of traditional assessment; this study sought to surface barriers and opportunities in the perceptions of legislative education committee members in relation to PAs.

## **Methodological Approach**

We report initial-phase design-based implementation research (Fishman, Penuel, Allen, Cheng, & Sabelli, 2013). Detailed field notes were collected to document the interactions between the LESC and members of the collaboratory who had been invited to present. The notes were analyzed using open coding with attention to opportunities for and barriers to policy change aimed to support assessment practices that create opportunities for learning. Once opportunities and barriers were identified, we looked for patterns within those categories.

## **Findings, Conclusions, and Implications**

The legislators raised questions and concerns about current and proposed assessment practices. They talked about teachers and classrooms they have known personally or have heard of, but few claimed expertise in education. They told stories to warrant some of their claims. But the personal stories may also limit legislators from being able understand perspectives beyond their personal experiences. Urban and suburban democrats brought concerns about how much they perceive that teachers teach to the test. This represents an opportunity for policy change, but is hardly a novel notion. We see other opportunities in the urban Democrats’ calls for reform of assessment, as well as the cross party laments about students’ lack of critical thinking skills (Table 1). Several LESC members who were past or current educators offered support for PAs. Barriers were also visible in the concerns raised, predominantly from Republicans. A rural/urban Republican who is a retired educator expressed concerns about teachers’ capabilities. Her lack of faith in the competency of teachers indicates a serious barrier to the potential for change in assessment policy.

**Table 1: Sample of codes identified, examples, and the political party affiliations of speakers**

<i>Description of code</i>	<i>Examples</i>	<i>Party &amp; Setting</i>
Opportunity: A need for reform of assessment	How long will we wait for assessment reform? Standardized tests might give a nice measurement, but the question is, what are they measuring?	Urban Democrats
Opportunity: Critical thinking identified as gap in student ability	Students do not have critical thinking skills at the core level, and they are not reading Universally we [the USA] are considered to not be teaching our students critical thinking and it can be traced back to NCLB	Rural/Urban Republican, Suburban Democrat
Barrier: Mistrust in teacher competency	Some teachers do not have the basic skills. They don't have basic grammar skills and they are not prepared. These are the facts. Who will deliver these assessments if not all teachers are ready to be teachers?	Rural/Urban Republican

As we continue to seek change in assessment policy, we will attend to the opportunities and barriers made visible in these interactions. It is clear, for instance, that demonstrating teacher impact and professionalism will be vital; we will be able to show this through the designs teachers create for PAs, the feedback that they give on drafts of student work as part of the PAs, and their engagement in a professional network to score PAs from other teachers' classrooms.

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## Acknowledgments

We acknowledge support provided by an Interdisciplinary Research grant from the College of Education in cooperation with the Office of the Provost, University of New Mexico.

# Tug of War: What is it Good For?

## Measuring Student Inquiry Choices in an Online Science Game

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**Abstract:** We designed and tested a computer game to measure middle-schoolers' science inquiry. In the game, students can run experiments or answer challenge questions. Students who use more of their chances for experimentation performed better on challenge questions and a posttest. Shorter times per experiment were associated with higher science grades. Choices to engage in inquiry predicted academic achievement better than accuracy. We conclude that science-learning assessments should measure inquiry choices in addition to knowledge.

### Measuring Students' Inquiry in Scientific Phenomena

Exploration allows scientists to test and form hypotheses about new domains. For students to become literate in the practices of science, they should engage in exploration and hypothesis testing, hallmarks of inquiry approaches to science instruction (e.g. National Research Council, 2007; Dunbar, 1993). However, current knowledge-based assessment strategies do not measure inquiry and exploration. We propose that using educational software to record students' choices can provide more information about their learning than typical assessments (Schwartz & Arena, 2013). Choice-based assessments are explicitly designed for open-ended exploration and are fundamentally different from technologies that make choices for the student.

We created a game to examine students' inquiry choices when learning a new idea in science. To win the game, students need to correctly complete eight questions in a row. They have repeated chances to run their own brief experiments about the topic or simply answer the eight challenge questions. We tested the game with eighth grade students and present preliminary findings relating their inquiry choices and academic achievement. We show that measuring inquiry, even with simple data-mining techniques, is useful for assessing students.

### Method

Eighth grade students ( $n = 136$ ) from a suburban middle school played an interactive computer game during class time late in the school year. The school was comprised primarily of Asian, Filipino, and Hispanic or Latino children; approximately 40% were socioeconomically disadvantaged. Thirty-six participants were excluded because of missing permissions and an additional nine were removed due to computer error. Our final dataset consists of 91 students. Participation was voluntary and did not affect students' class grades.

### Computer Game Environment

In the Tug-of-War science computer game, modeled after a PhET simulation on forces and motion (<http://PhET.colorado.edu>), students learn to predict the outcome of a simulated tug-of-war between two teams of up to four characters. The winning team is determined by summing the strength values of characters on the team, where the strength values are 1, 2, and 3 for the small, medium, and big characters, respectively. The character's position along the rope does not affect the result. Students were not given knowledge of either of these determinants and this topic was not previously covered in their science curriculum.

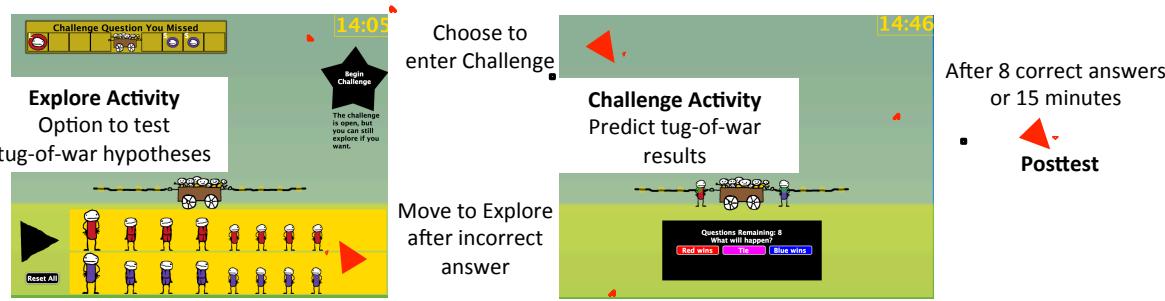


Figure 1. Paths through the Tug-of-War Explore and Challenge Activities

Students begin by manipulating a subset of the characters on a brief introduction screen designed to familiarize them with the Tug-of-War interface. After 60 seconds, students may enter the Challenge Activity, which involves predicting which team will win a tug-of-war (red team, blue team, or tie). Questions become

progressively more complex and are randomly drawn from a bank of possible configurations. Students must correctly answer eight consecutive questions to succeed in the challenge.

When students answer a challenge question incorrectly, they are sent to the Explore Activity. There, they can place characters on the tug-of-war teams and view the outcome as often as they want. This enables students to test hypotheses about the tug-of-war motion. As such, we call each “set-up and view” sequence a hypothesis test. Students are free to reenter the Challenge Activity at any time, even without testing any hypotheses. The Tug-of-War game ends either when a student succeeds in the challenge by answering eight questions or after 15 minutes have elapsed. Next, all students completed a brief computerized posttest that showed one side of a tug-of-war configuration and displayed an array of ten possible opposing teams. Students were asked to select all of the teams that would tie against the example team.

## Results

We report two measures of students’ exploration choices. First, we computed a *proportion of exploring* variable. At two points in the game, students have the choice of performing a hypothesis test or entering the Challenge Activity. These points occur when students enter the Explore Activity and after each hypothesis test. We call these decision points *opportunities to explore*. *Proportion of exploring* is computed by dividing each student’s number of hypothesis tests by his or her total opportunities to explore. The average value for this variable was 0.44 ( $SD = 0.23$ ), indicating that students took advantage of 44% of the opportunities to explore. On the remaining opportunities, students returned to the Challenge Activity. Next, each student’s *mean explore time* was computed by finding the average time he or she spent on each hypothesis test. Students spent an average of 13.12 seconds ( $SD = 6.50$ ) per hypothesis test.

### Game Choices Predicting Posttest Scores

Students’ scores on the posttest served as a measure of in-game learning. On average, students performed at 79% accuracy in selecting the correct teams. Twenty-seven students received a perfect score on the posttest. We found that students who completed the challenge (79 out of 91) during the game performed better on the posttest than those students who did not complete the challenge ( $t(89) = -2.57, p = 0.01$ ). Next, we investigated whether children’s exploration choices affected their posttest scores. While *mean explore time* did not predict posttest outcomes ( $r = -0.09, p > 0.05$ ), *proportion of exploring* positively correlated with posttest scores ( $r = 0.21, p < 0.05$ ). Students who chose to use more exploration opportunities learned more.

### Game Choices Predicting Academic Achievement

We obtained students’ second trimester 8<sup>th</sup> grade science class grades. Students’ average class grade was 81% ( $SD = 9\%$ ). Students’ posttest performance was correlated with class grades ( $r = 0.29, p < 0.01$ ). We examined relationships between exploration and science class grade. *Proportion of exploring* was not significantly related to class grade ( $r = 0.05, p > 0.05$ ). We found that *mean explore time* negatively correlated with class grade ( $r = -0.29, p < 0.01$ ); students who complete hypothesis tests faster tend to have higher class grades. Perhaps this implies that students who are more efficient with their in-game exploration do better in school tasks, which fits with the design-thinking model of encouraging rapid iteration. Moreover, *mean explore time* provides predictive power for class grade beyond posttest performance ( $r = -0.28, p < 0.01$ ).

## Implications

Most academic assessments place a great deal of emphasis on retrieving verbal memories and executing procedural skills. Outside of school, however, students must continue to learn, as classrooms cannot prepare individuals for everything they must know. Here, we created a computer game where students had to learn to beat the game. We showed that inquiry choices could predict student performance within and outside the game. These choices within the game, not only posttest performance, predicted academic performance.

Going forward, we plan to pursue more fine-grained analyses to better characterize students’ exploration patterns. We have created variables to describe the semantics of students’ hypothesis tests, such as recording if students isolate an individual character on a side of the tug-of-war. We hope that investigations of detailed choices will complement our results and reveal more about students’ inquiry in science domains.

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## Acknowledgments

We thank Jacob Haigh and Neil S. Levine for their work programming and designing the Tug-of-War.

# **Educational Games in the Classroom: Design-Based Research and Methods for Classroom Mediation**

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**Abstract:** Educational games are becoming popular tools teachers use in the classroom to improve students' learning and understanding. This poster describes a large, ongoing design-based and mixed-methods research study that examines the best practices for using games in the classroom. We created three video games that target fraction learning. We aim to study the affects of these games on learning and engagement in the classroom and to understand what contexts facilitate the greatest math learning.

## **Introduction**

This research is part of a collaboration between computer scientists and learning scientists. The learning science teams conduct classroom-based research to study the games, and as findings are discovered, those results are shared with the computer scientists who quickly revise the games for continued use and study in the classroom. The affordances of technology and our close collaboration allows us to rapidly iterate on both game design and study design as a means to track and improve the use of games in the classroom.

In the 2012-2013 school year, our group conducted eight classroom-based studies. Our chief goal is to help students productively engage in the discipline of math as a means to improve their conceptual understanding of fractions. The research questions guiding the studies are: 1) What do different uses of the games look like in different classrooms?; 2) If we see different learning outcomes with different implementations, how were those implementations qualitatively different?; 3) What implementation processes should be repeated to reproduce learning gains in other classrooms?; and 4) How should both study and game designs change when statistically significant learning gains are not produced?

## **Theoretical Framework**

Our research is supported by sociocultural theories of learning, which examine the cultural and contextual nature of human development (Bronfenbrenner, 1979; Lave & Wenger, 1991; Rogoff, 2003; Vygotsky, 1978). In our studies we are mindful of the overall "ecology" of gaming as described by Salen (2008), therefore we do not study games without regard to the context in which they are played. Looking at the learning ecologies allows us to think of gaming beyond just the game and play state to also consider the game and its context as a complex system.

The social interactions and supports that occur during game play help players figure out the game in very different ways (Steinkuehler, 2004). Players playing together online or alone-together online (i.e. MMO) support each other differently than those playing a multi-player console game in the same physical space, and different still from those playing single-player games together in the same physical space (Salen & Zimmerman, 2003; Stevens, Satwicz, & McCarthy 2008).

## **Methods**

Aligned with our framework, we employ a design-based research methodology (Penuel, Fishman, Cheng, & Sabelli, 2011; Sandoval & Bell, 2004) to study these complex systems and revise both our games and environments as we learn and change. Our systematic investigations are iterative and collaborative, and we are concerned with developing theory related to how games can best be used in the classroom.

## **Findings**

There are three categories of studies: 1) Unmediated game play studies, 2) Peer mediated game play studies, and 3) Teacher mediated game play studies.

### **Unmediated Game Play**

Overall, we did not find significant learning gains for unmediated game play (i.e., game play without teacher intervention and without peer support). These findings led us to move away from unmediated game play in the classroom, towards the use of peer mediated game play. Our game designers programmed a two-player version

of *Creature Capture* for the study of peer mediated game play. In addition, we tested the use of *Refraction* if played in pairs (although the game was not redesigned for this use).

### **Peer Mediated Game Play**

The second set of studies examined peer mediated game play. In these studies students played the games with a partner as a form of additional support but without supporting classroom activities surrounding the game. As expected, peer-mediated game play was associated with statistically significant gains on the assessment for some groups and more math talk than unmediated game play. While peer mediated game play was an improvement, we were interested in exploring the contexts and conditions that affect learning via the use of games. As a result, we examined the impact of teacher mediated game play on student learning.

### **Teacher Mediated Game Play**

The third set of studies are those for which teachers integrated the games into their classroom instruction. In general, the lower performing students, who received more focused instruction, produced statistically significant learning gains. As a result, this led us to create more focused teacher-led interventions around the games.

## **Discussion**

These studies tell a story of continued improvement in study design, game design, and student learning over the course of a year. Two types of learning occurred as a result. The first was continual research learning in the context of the designed based research. With each study iteration, we were able to draw new conclusions, create new hypotheses, and quickly test those out in the classroom. The second level of learning relates to student learning. As we increased the level of structured mediation around the gameplay, students learned more.

## **Implications**

First, for teachers who use games in the classroom, our findings help demonstrate that using games in isolation may not be the best use of games in the classroom for learning. Instead, structuring game play and the game play context in a way that is more deliberate and planned, and with the inclusion of peer or teacher mediation, will likely promote more student learning. Second, we are moving towards a more careful understanding of what types of teacher mediation and classroom contexts are most helpful for student learning. We believe that directed lessons around the games might be the most beneficial.

## **Relevance to the Conference**

Our study and our process embody the ideas of learning and becoming in practice. For the students, we aim to foster learning that promotes students engagement with mathematics and math talk as a means to productively engage with the discipline. As researchers, using design based research is one way in which we are constantly learning and improving in our practice.

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## **Acknowledgments**

We would like to thank the Bill and Melinda Gates Foundation and the Office of Naval Research for making this work possible.

# **“What in the world?” Animated Worlds in Multivariable Modeling with Motion Chart Graph Arguments**

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**Abstract:** This poster presents part of a design study that engaged prospective secondary mathematics teachers in multivariable modeling practices to support learning about critical mathematics and statistical literacies. Student pairs constructed graph arguments about global development using an online, dynamic graphing tool (motion chart). Interaction analysis of sequences of student trouble suggests that animating representing and represented worlds and laminating historical narratives to the mathematical display encouraged success in the activity.

## **Motion Charts, Modeling and Mathematical and Statistical Literacies**

The motion chart (Al-Aziz, Christou, & Dinov, 2010; Rosling, Ronnlund, & Rosling, 2005) is a new, dynamic, digital, representational form for modeling multivariate data over time, freely available, along with large public datasets, on Gapminder’s website ([gapminder.org](http://gapminder.org)). This study treats motion charts as comparable in nature to complex, Big Data visualizations used to produce STEM arguments that increasingly appear in public media spaces. A discussion of mathematics and statistics in the world thus framed the Gapminder activities. We hoped that positioning secondary mathematics teachers as consumers and authors of arguments with motion charts about global development would push them to build upon their reading of Gutstein’s (2003) contrast of critical and functional mathematical literacies and to consider “reading and writing the world” using models.

Accordingly, how do prospective math teachers make sense of this modeling activity? Applying Ochs, Gonzales, and Jacoby’s (1996) framework for how laboratory physicists animate different worlds in talk to construct models to describe physics experiments, we contend that successful modeling practices with motion charts (constructing and evaluating graph arguments that explain and compare nations’ development trend lines) depend on the animation and lamination of relations between represented (global health and wealth) and representing worlds (the tool and datasets) (Gravemeijer, 1994; Hall, 2000). We seek to explore at the microanalytic level of multimodal, sequential interaction an emerging practice of modeling that accounts for how students used Gapminder to animate complex, multidisciplinary, multivariable data and bind a crafted narrative of historical change to a dynamic, mathematical display to compose a compelling graph argument.

## **Theoretical and Methodological Approaches Pursued in the DIY Activity**

The modeling task was part of a larger design study (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003) in a required Mathematics Literacies course at an elite university in the Southern U.S., spanning three 3-hour classes over four weeks. We first asked students to find and dissect mathematical or statistical arguments in public media. We then introduced students to Hans Rosling’s (Gapminder’s designer) Gapminder performances. Students then used Gapminder to imitate and remix Hans’ arguments and to make their own graph arguments in a DIY activity to perform in the next class. Data reported come from the DIY activity in the last 70 minutes of the second class. The course instructor identified two student pairs for selective case study comparison (Flyvbjerg, 2006): masters students Nathan and Nicole (N&N) and undergraduates Cara and Tara (C&T). We considered all students as nonexperts in graph argument performance creation (as compared to Hans). We captured a HD video record of each focal pair working at a table with two computers.

## **Trouble with “Interestingness” in Animating and Storify-ing Worlds**

Analysis focuses on the multimodal activity of modeling (talk, significant gesture, interaction with computer(s) and Gapminder display). Initial structural analysis segmented the 70 minutes of video data for both student pairs in order to compare their *graph argument paths*, following their transitions between models, each defined as selection of a unique pairing of X- and Y-axis indicators from the dataset and unambiguously mentioned in talk. We considered whether or not students *played* the graph so that the model displayed changing indicator values through time and how often student(s) examined a given model. We compared three model paths: one for N&N who worked on a single computer, one for C, and one for T, who worked side by side on separate computers. We then used interaction and conversation analysis (Jordan & Henderson, 1995; Schegloff, 1991) to explore the sequential organization of trouble and repair in these model assembly pathways as student pairs continually generated models using Gapminder. We identified three categories of trouble: (a) when a country’s trail violated expectations (e.g., increase in life expectancy with an increase in alcohol consumption); (b) when tool unfamiliarity left stories untold (e.g., forgetting to select country trails to show change over time when playing the graph), or (c) when there was confusion with quantities (e.g., CO<sub>2</sub> per person vs. yearly CO<sub>2</sub> emissions). Next, using patterns of students’ announcements of trouble, we delved into animation and lamination in student talk (at the level of predicate structures) and gesture. We looked at the ontologies of story fragments related to

health and economic processes unfolding. As in Ochs et al.'s (1996) analysis of physicists, we conjectured that Gapminder modelers hybridize stories of country development with a visually, dynamic graph to collaboratively and progressively build and refine (Collins, Joseph, & Bielaczyc, 2004) what they feel are "interesting" models for public performance. While the larger corpus of data has been reviewed with this analytic framework, a detailed microanalysis and transcription is complete for the first 10 minutes of each video record and for a second 10 minutes when each pair approached a model close to the final graph argument presented in class.

## Preliminary Findings and Discussion

This study offers new insight into how prospective secondary math teachers variably understand a novel genre of modeling practices as a critical mathematical literacy. Though both pairs worked serially through indicators for X- and Y-axes, selected 'interesting' variables that were personally relevant, socially taboo or trendy, determined model misfit (i.e., an "uninteresting" display was unfit for this task), and argued about alternative variables and measurements, the comparative analysis of model paths showed little collaborative progressive refinement (Collins et al., 2004) for C&T as compared to N&N (e.g., N&N often returned to models while C&T never revisited a model). N&N activated and aligned the represented and representing worlds of motion charts, as evidenced by the ways in which they communicated understandings of quantities and the graphing tool, engaged in historical inquiry to contrast and explicate relationships between health and wealth of nations, and explicitly considered development over time by regularly playing models. Similar to Ochs et al.'s (1996) physicists, N&N used hybrid utterances to describe and narrate the graphical representation. Indeed, the motion of the motion chart afforded N&N possibilities for seeing and telling historical, social, economic narratives based on power relations. Their common modeling environment (one screen), which helped N&N focus their model path, also likely supported their productivity. In contrast, C&T's division of labor across separate modeling environments (two screens) led to diverging model paths, model abandonment and less consistent and frequent engagement in the animation of worlds. As they moved from model to model, especially at the start of the DIY, C&T did not regularly play the world, which restricted their capacities for animating explanations, for considering change over time, and for embracing the tool's "messiness"—its dynamic and multivariable qualities (e.g., they mostly treat the display as static scatter plot, like a conventional school statistical display). Such a stance, akin to a functional mathematical literacy perspective, created challenges for describing the graph animations narratively to compare varying historical anecdotes of development for particular nations. Additional analysis will continue to describe the processes of animation and lamination of conceptual worlds to support deeper connections between this new domain of modeling practices and critical mathematical literacies.

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# **Productive Disciplinary Engagement: Examining Negotiation of Group Activity with Multiple Frameworks**

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**Abstract:** Productive engagement in meaningful activity is essential for learning and becoming in practice. However, learning systems that support such engagement are complex and usually studied in single contexts making findings difficult to transfer. We detail research among four universities who study these systems in different contexts. We illustrate how each university examines the negotiation of group activity and how their different frameworks and methodological approaches overlap, are complementary, and can be integrated.

## **Introduction**

Productive engagement in meaningful activity is essential for motivation and progress toward flexible, adaptive expertise in science, technology, engineering and mathematics (STEM). However, learning systems that support engagement in this way are complex and difficult to scale. Such systems are usually studied and designed in single contexts, so the knowledge gained is difficult to transfer to new settings. We report on joint research among universities from Australia (U1), Finland (U2), and the US (U3 and U4) who study these systems. We aim to identify unifying themes and develop generalizable understandings about supporting *productive disciplinary engagement* (Engle & Conant, 2002) in STEM and capture the kind of interaction likely to result in deep learning of concepts and incorporation of practices. We focus on group settings in authentic contexts, where students must integrate and flexibly apply those concepts and practices. Using a single data set, we compare two frameworks: (1) metacognitive regulation (MR) and (2) negotiating a joint enterprise in “figured worlds.” We examine how students engage and interact with one another as they work in groups.

## **Negotiation of Group Activity in Productive Disciplinary Engagement**

Engagement has been defined generally as “active, goal-directed, flexible, constructive, persistent, focused interactions with the social and physical environments” (Furrer & Skinner, 2003, p. 149). Engagement is productive when conceptual or practical progress on a problem is made over time and is disciplinary when students use the discourse and practices of a discipline in their work together. We operationalize productive disciplinary engagement as learners using the discourses and practices of the discipline in the projects to “get somewhere” (develop a product, gain better understanding) over time.

### **Framework 1: Metacognitive Regulation (MR)**

U1 and U2 use this framework with different methodological approaches; U1 applies co-regulation and U2 applies socially shared metacognitive regulation (SSMR). Both share theoretical assumptions of MR (Volet, Vauras, Khosa, & Iiskala 2013) focusing on how students of a group jointly regulate their cognitive processes to progress towards shared goals. The core idea is to understand MR and communication as students work together in student-led, challenging and collaborative learning systems. A group is a social system of multiple regulating participants with both group and individual levels, making it necessary to consider self- and social regulatory processes as integrated. The first approach, co-regulation, combines the constructs of social regulation and content processing as two dimensions of socially-regulated learning (Volet, Summers, & Thurman, 2009). Social regulation occurs on a continuum from the individual level to the preferred group level, labeled co-regulation. Content processing occurs on a spectrum from low to high level. Two orientations of cognitive engagement have been identified: task co-production and knowledge co-construction (Volet et al., 2013). We use these categories to examine the flow of group activity from the viewpoint of MR. The second approach is referred to as SSMR, which refers to the students’ goal-directed consensual, egalitarian and complementary monitoring and regulation of joint cognitive processes in collaborative learning (Iiskala, Vauras, Lehtinen, & Salonen, 2011). This approach was utilized reliably to identify different foci and functions of SSMR (Iiskala et al., 2011). The foci and functions of SSMR are analyzed in this work.

### **Framework 2: Negotiating a Joint Enterprise in “Figured Worlds”**

U3 examines how individuals within student groups negotiate to reconcile what the group is trying to

accomplish together, i.e., their joint enterprise (Nolen et al., 2012; Wenger, 1998). In addition, this perspective incorporates “figured worlds” (Holland, Lachicotte, Skinner & Cain, 1998; Jurow, 2005) as a way to examine the social worlds in which students are simultaneously immersed. In our illustrative case, students are immersed in the “school world,” where they must satisfy instructor expectations, and the “engineering world,” i.e., the world of practicing engineers. Each world has distinct values and roles, which sometimes conflict. The closer a group’s joint enterprise is to what occurs in engineering practice, the more authentic the activity. In addition to negotiating the joint enterprise, groups negotiate a division of labor and workflow. With regard to the negotiation of group activity, this perspective affords investigation of the nature of a group’s joint enterprise, the roles students play in negotiation of that joint enterprise, the actions or moves students make during negotiation, and the influence of the negotiation process on the joint enterprise over the course of the project.

## Methods

U4 provided the context for the illustrative case. The project studied was delivered in a laboratory course typically taken by students in their final year of an undergraduate engineering program. The three week project was designed to engage students in solving a “real-world” engineering problem via the use of industrially-sized virtual equipment (Koretsky, Amatore, Barnes, & Kimura, 2008). One group of three students was chosen for study because of their high level of engagement as measured by the number of hours they dedicated to the project. The group was audio-recorded and observed any time two or more members met. Analytical methods consistent with studies described above were used on transcripts of the audio-recordings.

## Preliminary Findings, Conclusions and Implications

Comparing the frameworks and methodological approaches highlights benefits of each. This poster shows how these different frameworks overlap and are complementary, each emphasizing a different aspect of negotiation in group activity. Their applicability to this new data set means that they can likely be applied, either individually or in an integrative way, to new contexts.

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## Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant Nos. EEC 1261930 and EEC 1261892. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. We would also like to acknowledge all of the individuals who participated in the studies associated with this work and the people who supported this work with their time and help.

# **Everyday Life Science and Engineering: Bridging the Gap Between Formal and Informal Learning among Native American Students in the Northwestern United States**

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**Abstract:** This poster explores Native American student ideas regarding science and engineering and tries to understand how they bridge the formal and informal perceptions of these two disciplines. Students from a tribal community in the Northwest participated in a summer camp that focused on merging indigenous and non-indigenous knowledge systems about science and engineering. Using drawings, storytelling and interviews, the study discusses learning processes associated with youth who live in one Native American community as they develop an understanding of science and engineering phenomena.

## **Introduction**

Even though there is overwhelming evidence that suggests that learning is a socio-cultural phenomenon, designing learning environments for Indigenous students is a challenging endeavor (Aikenhead, 1995, 1996; Smith, 1982, 1995; Snively, 1990, 1995; Wright, 1992). In order to create an optimal learning environment for Indigenous students, not only does the content have to be culturally relevant, but it also needs to be aligned with the learning processes of the students (Bang & Medin, 2010). As students move through formal (school) and informal (out of school) spaces, families, friends, teachers and communities become primary sources of knowledge, while local ways of knowing become the processes through which students realize the knowledge (Bell, et al, 2007).

This study examines Native American students (from one tribal community in the northwestern United States) perceptions of science and engineering as they move through formal and informal learning spaces and struggle with Eurocentric and indigenous epistemologies. The study is designed to find out how students connect science and engineering phenomena to their everyday life, so as to bridge the gap between the formal and informal learning spaces that they experience. The research questions that the study seeks to answer are as follows: 1. What perceptions do Native American middle school students from one tribal community in the northwestern Unites States have about science and engineering? 2. How do these students negotiate their perceptions and understandings of science and engineering as they move through different learning spaces? 3. How do the students understand science and engineering as a part of their everyday lives?

## **Theoretical Background**

This research takes into consideration that theories in socio-cultural learning try to understand ‘what people think’ (Banks, 2007), while the collateral learning theory tries to understand ‘how people think’ (Solomon, Scott & Duveen, 1994). Socio-cultural learning theories emphasize that learning is contextual and is supported by various societal constructs (Barron, et al, 2009). Collateral learning, on the other hand, tries to explain how the students make sense of what they know (Aikenhead & Jegede, 1999). Jegede, 1995 proposes that there are four types in collateral learning processes – Parallel, Simultaneous, Dependent and Secured. Collateral learning theory tries to explain how indigenous students might store conflicting ideas (Eurocentric Scientific and indigenous) in their long-term memory. For example, parallel collateral learning is observed when indigenous students construct Eurocentric science concepts parallel to the indigenous concepts, with very little interference and interaction between the two. For optimal learning to happen it is important that both ‘what students think’ and ‘how they think’ are merged together (Bang, Medin & Atran, 2007). To this end, the research questions in this study are designed to understand what students think and how students think about science and engineering phenomena. The first research question is designed to understand ‘what’ do the students think about science and engineering phenomena, while the second and third research questions emphasize ‘how’ students negotiate their understanding of science and engineering phenomena in formal and informal learning spaces, and as part of their everyday lives.

## **Study Design**

The students attended two non-consecutive week long summer camps focused on science and engineering. The first camp focused on traditional practices in science and engineering design (building fish weirs, surveying)

while the second camp focused on discussing science and engineering as tools to resolve environmental problems that are related to the watershed that their community resides on (how would you put the practices together to solve problems). The second camp used story telling as a pedagogical tool to help students put the engineering practices together in order to think through solving environmental problems related to the watershed.

The students' perceptions of science and engineering were gauged using the following methods: After the students discussed several traditional and Eurocentric science and engineering practices during the first camp, they were given a drawing task at the beginning of the second camp. In this activity, students were asked to draw a community that they would like to live in and show in their drawing how science and engineering played a role in their community. The purpose of this activity was to observe student understanding of science and engineering phenomena and also their perceptions of how science and engineering phenomena play a role in their community/everyday lives. This was a group activity, which involved students sharing ideas about science and engineering in order to draw a map of their community. Each group included four to five students. We then conducted delayed post interviews four months after the camp to find out student perceptions of science and engineering phenomena after a period of time, and how students think about science and engineering phenomena as a part of their everyday lives. Although the student drawings were created as a group, interviews about the drawings were conducted individually allowing us to explore individual student perceptions and understandings.

## **Participants**

22 students in grades 4-6 participated in the summer activities. 11 of those students from one of the tribal communities participated in the study.

## **Results and Discussion**

In the drawing activity, when asked to draw a community and show examples of science and engineering in their community, students chose to draw examples of practices that they had learned in the first weeklong camp. For example, some students drew fish weirs in their community as a science and engineering phenomena. They had learned about fish weirs in the first camp. The majority of the students expressed science and engineering as a phenomenon that involves 'building'.

When students were asked in the interview to point out how the science and engineering practices in their drawing played a role in their everyday lives, most of them could not answer the question. For example, students recognized that fish weirs are used by scientists to capture and tag fish. However, they were not able to connect that practice to how fish-tagging helps make management decisions on fishing practices that are a part of everyday life..

Both the interviews and the drawing activity gave us insight into how students negotiate ideas about science and engineering as they move through different living and learning spaces. In the examples discussed above it is clear that the students think of science and engineering as something that they learn at camp. They are not able to make the connection to their everyday lives. Thus one can observe a clear case of parallel collateral learning. In this case the students' ideas of science and engineering remain limited to their experience in the camp. As observed in the delayed post interviews, the knowledge (fish weirs) remains with them in their long-term memory but they are not able to fit the knowledge in their everyday life context.

In the delayed post interviews, some students mentioned houses and cars as science and engineering phenomena in their everyday lives. However, cars and modern time house designs are viewed as concepts grounded in Eurocentric science and engineering phenomena and therefore are difficult to connect to indigenous ways of knowing. This is a problem faced by many designers of learning environments for indigenous students. Using data from the interviews and drawings in this poster we hope to spark a discussion about how to design effective learning environments for helping Native American students learn about their traditional science and engineering practices and connect those practices to their everyday lives. Curriculum designers may consider implementing strategies designed to bridge the gap between Native Americans home culture and the culture of Eurocentric science. This study is a preliminary study and further research is needed to address Native American students' needs concerning culturally relevant curriculum and instruction.

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# Distributed Cognition and Gesture: Propagating a Functional System Through Impromptu Teaching

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**Abstract:** On a beach in France, a lifeguard makes three attempts to teach a colleague how to use a wristwatch and the sun to find compass directions. Each attempt involves constructing and coordinating representations in multiple spaces: sand, surroundings, watch, and air (gesture space). Close examination reveals how the hands, eyes, and body construct and connect these representations and enact their coordination in a cognitive functional system.

## Overview

In keeping with the conference theme of “Learning and Becoming in Practice,” this poster examines aspects of distributed cognition and gesture (Williams 2013) in impromptu teaching in an outdoor work setting. The data consist of a video-recording of a lifeguard on a beach in southwestern France teaching a colleague how to locate cardinal directions using an analog wristwatch and the position of the sun. The lifeguard makes three attempts to teach his colleague how to coordinate these elements to fix south and from there to locate north, east, and west. Our poster examines in each of these attempts, rendered as a sequence of annotated images, how orchestrated movements of the hands, eyes, and body guide conceptualization (Williams 2008ab). From this analysis, we argue for a distributed view of human cognition, situated view of instruction, and embodied view of teaching.

## Distributed Cognition: Cognitive Functional Systems

Among the most distinguishing features of human cognition is how brain, body, and world interact to produce impressive cultural and cognitive achievements (Clark 1997). Hutchins (1995) argues for a distributed perspective on human cognition: he claims that cognitive activities are accomplished through coordinations of conceptual and material elements in functional systems. In moments of human practice, we instantiate functional systems to transform inputs (say, a configuration of hands on a clock face) into outputs (a time reading [Williams 2008ab]). Functional systems involve ways of perceiving and acting that coordinate system elements to fix the targeted outcomes. Cultural processes preserve and perpetuate the material artifacts, cognitive models, and bodily practices of conventional functional systems. Much of schooling is devoted to mastering these systems so children can instantiate them in everyday life and keep them extant in our culture.

## A Functional System for Finding Directions

The data analyzed in this poster relate to the functional system shown in Figure 1, reproduced from “Use your wristwatch as a compass” at lifehacker.com. The directions on the lifehacker website are simple: “Hold a watch with 12 o’clock at left. Move your arm so the hour hand points at the sun. The spot halfway between the hour hand and the 12 is south.” During Daylight Saving Time, find the spot halfway between the hour hand and 1. This system works in the northern hemisphere when the sun is visible and an analog wristwatch is present. Once south is fixed, the user can use a mental model of the compass rose to locate north, east, and west.

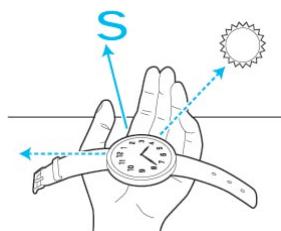


Figure 1. Using a Wristwatch to Find South.

## The Teaching Situation: On the Beach

The data were recorded by Simon Harrison on the beach at Anglet, in southwestern France, in July 2011. In the video, the lead lifeguard is trying to teach another lifeguard how to find south using this system, while a third lifeguard watches. It is early afternoon and the sun is visible, but the lead lifeguard is wearing a digital (not analog!) wristwatch, and there are no traditional drawing or writing tools readily at hand. The lifeguard is confronted with the problem of how to represent: (1) the elements of the system, and (2) the process of bringing them into coordination to locate south. In particular, the expert needs to represent the elements and operations in such a way that the novice can understand the system and use it successfully; in this case, the expert needs to do so while simultaneously monitoring the swim zone, his primary work task.

## First Attempt: Sand and Surroundings

The first attempt at instruction is rendered on the poster in filmstrip form as in Figure 2 (below), adapted from Williams & Harrison (2012). It involves the construction of a diagram in the sand, gestural enactments over the diagram, and coordinated gesture and gaze shifts to link represented elements to the geographic surroundings.

## Second Attempt: Sand, Digital Watch, and Air (Personal Gesture Space)

The second attempt is rendered in filmstrip form (a portion is shown in Figure 2) with annotations of bodily actions in representational spaces coded by color (sand in blue, digital wristwatch in lavender, and the air in front of the speaker [personal gesture space] in red). Speech is rendered as text in English (translated from French). Most of the instructional gestures are enacted over material representations, with only a brief interlude of gesturing in personal space, first to establish a virtual structure and then to model an object in relation to it.

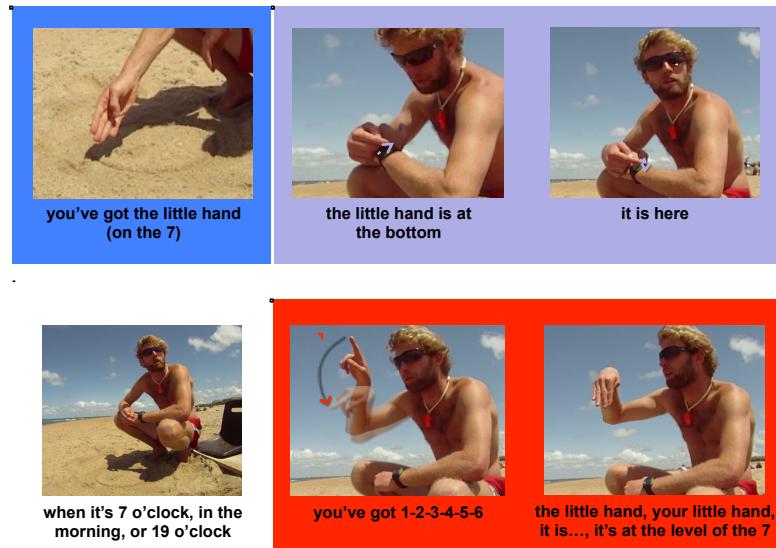


Figure 2. A Portion of the Second Attempt

## Third Attempt: Watch, Surroundings, and Enactment

The third attempt is likewise rendered in filmstrip form (as in Figure 2) and includes a full-body enactment of the process of coordinating the represented virtual elements of the functional system to fix south.

## Discussion

In his instructional discourse, the lifeguard constructs and coordinates representations in four different representational spaces: in the sand, in the surrounding environment, on top of his digital wristwatch, and in the air in front of his body (personal gesture space). The poster considers the different affordances of each of these spaces and analyzes the following: (1) how the lifeguard creates representations in the different spaces; (2) how he signals shifts between representational spaces while linking their counterpart elements; and (3) how he enacts the process of coordinating these elements in a functional system to find directions. In particular, the analysis focuses on the use of the body in situated instruction, highlighting how bodily orientation, gaze, gesture, movement, and speech are orchestrated to guide conceptualization. The poster closes with implications for our understanding of teaching as an embodied, situated activity and of the functions of gesture during instruction.

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# **Two Systems, Two Stances: A Novel Theoretical Framework for Game-Based Learning**

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**Abstract:** Recent reviews of the research on game-based learning agree that digital games as pedagogical tools add limited value. A more sophisticated theory of learning is clearly required to advance game-based learning research. This poster presents our efforts to conceptualize game-based learning within a more general framework for human cognition, the “two-system” model. Our extension of this model mechanistically explains some of the complexities of game-based educational research and provides several potentially interesting research vectors.

## **Introduction and Goals**

Reform perspectives on science education highlight the role of models in promoting student learning (Committee on Science Learning, 2007). Computer simulations are useful for modeling complex processes and relationships which are difficult to observe directly (Windschitl & Andre, 1998). Clark, Nelson, Sengupta & D’Angelo (2010) argue that digital games can be accurately described as simulations encased within game-like structures to increase student engagement, provide effective feedback, and promote self-efficacy. However, recent reviews have suggested that digital games provide only limited educational benefits (Young et al., 2012). The increasing sophistication of educational games promises to improve their outcomes, however, a unifying causal model that explains how people learn from games has remained elusive.

The goal of our proposed framework is to support a more sophisticated understanding of how and what people learn from digital games. We are motivated by the strong contrast between recent scholarship that finds little evidence that people learn much from digital games (Young et al., 2012). Opposite to that finding is the observation that players inhabit rich ecologies of knowledge about the games they play (Gee, 2007). The disconnect between the relatively low efficacy of games for learning and the often-impressive feats of cognition and inquiry observed by gamers “in the wild” motivates us to develop a more robust theoretical framework.

## **Software Models and Mental Models**

Aside from principles related to multimedia learning, mental models are frequently featured as the causal mechanism behind learning outcomes from digital games. The proposed mechanism for game-based learning is that students purposefully investigate the digital environment, “try hard to make sense” of it, and the product of their effort is a “coherent mental model” (Moreno, Mayer, Spires, & Lester, 2001, p. 185). This model enables students to solve problems both within the game *and* at a later time and in different context.

Our premise is that players do not necessarily form accurate mental analogues of the software models that drive the phenomena they experience in-game (i.e. the encased “simulation”); rather, they create a second-order model (i.e. a “simulacrum”) that is oriented towards explaining the functioning of the simulation, predicting future states, and allowing the user to feel she understands the simulation and is in control of it.

## **“Learner” Stance and “Player” Stance**

A person might have two distinct goals when engaging with their simulacrum. The first is to understand the simulation, its objects and relationships. The second is to use the simulacrum as a laboratory where actions can be planned and evaluated in terms of their effectiveness at creating a desired state. A student playing a digital game is constantly shifting in stance between (a) a problem-solver seeking a specific desired outcome, i.e. winning, and (b) an explorer purposefully and systematically investigating the operating principles of the virtual environment. These two sets of goals imply different forms of thinking. A user in the inquiry (or “learner”) stance might probe the simulation for information that confirms their understanding. A user in the mastery (or “player”) stance might engage in exploratory actions and observing if these actions lead to positive results.

## **The 2SM in Action**

The interaction between the simulation and the simulacrum can be conceptualized using a two-system model of cognition (see Evans, 2008). Two-system models of cognition distinguish between effortless thought, or “intuition”, and deliberate purposeful “reasoning”. These modes of cognition are neutrally labeled as System 1 and System 2, respectively. The former is described as fast, automatic, associative, emotional, and opaque; the

latter as slower, controlled, serial and self-aware. In our framework, we associate System 1 with the “player” stance and System 2 with the “learner” stance.

Starting from the two-system model of cognition, we propose this mechanistic explanation for how people play and learn from digital games. A person begins play, and a goal will be suggested to the player’s thinking, immediately triggering a self-query, “how do I achieve this goal?” The self-query shifts the person towards the learning stance, and in response to the query a simulacrum is constructed. This simulacrum’s functional requirement is that it suggests actions that will bring the simulation closer to the goal state. These actions are rendered as execution steps (“Do that”) and enacted in the simulation through the game’s interface. Actions that prove effective are reinforced and actions that have a negative effect are rephrased as avoidance steps (“Don’t do that”). With repeated reinforcement, effective rules are matched to the context cues from the environment, and stored as conditionals, i.e. “If this, do that.” These conditionals are easy to remember, quick to access, and require nearly no cognitive effort to execute: they fit the functional definition of heuristics.

Whenever the player finds themselves in a situation that is covered by one of her stored rules, she will in most cases default to doing what that rule stipulates. In other cases, the person must shift to a learning stance, reinstate the simulacrum and use it to find new possible actions. The simulacrum that is rebuilt is based on the one last used, since reinforcement of effective actions also reinforces the simulacrum that suggested that action. If the player is never without a rule to apply, the simulacrum is deactivated as the person defaults to System 1-style processing, i.e. fast, effortless, intuitive heuristics. Through play, a person gathers three forms of knowledge about the game: (a) the conditions that the game presents, (b) a set of heuristics, i.e. rules of action whose activation criteria match these conditions, and (c) a simulacrum, or second-order mental model, of how the game produces the conditions.

## Implications and Possible Lines of Research

The baseline assumption of mental-model accounts of game-based learning is that once learners form their mental models, these models remain available in other contexts. Our framework problematizes that assumption since simulacra, like all System 2 processes, are pre-empted by System 1 processes such as rules and heuristics whenever these are available (Schwartz & Black, 1996). Given that System 1 is the preferred mode for everyday thought, it is unlikely that students retain a mental model that is useful in new contexts. How then can designers disrupt the learners’ natural tendency to discard simulacra and reason from heuristics?

One possible approach is to design an educational game that is constantly offering new goals as well as rules and constraints. Since the player cannot cope with them using existing heuristics, she must shift back into the learner stance, reinstating the simulacrum. If this happens frequently enough, the student may eventually become habituated to reasoning from a context-unbound mental model, rather than context-bound heuristics. This may result in greater availability of the mental model for problem-solving in other contexts. This design approach suggests a radically different form of educational game, featuring a constantly increasing novelty, escalating complexity, and tighter coupling between the player’s goals and the software model. Our first challenge is to build a game upon these two principles, and assess its effectiveness vis-à-vis alternative designs.

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# **Keeping Up: Shifting Access to Gateway Resources in a Cycling Community of Practice**

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**Abstract:** While learning involves changes in one's participation within a community of practice, changes in participants can also change access to resources key to newcomer participation. This poster presents a case study of a recreational cycling community illustrating how community changes diminished newcomers' access to resources for drafting.

## **Introduction**

A core tenet of sociocultural research in the learning sciences is that learning involves shifts in participation in the practices of a community (Lave & Wenger, 1991; Rogoff, 1991). In this view, newcomers begin as legitimate peripheral participants relative to an existing community. By navigating the community's pathways to acceptance, the newcomers become full participants in the community. Regardless of the nature of these paths, membership in the community, and thereby learning, requires access to the social and material resources of the community (Nasir & Cooks, 2009). Without access to these resources, newcomers remain marginal to the community or may cease participating altogether. We argue that, in some communities, access to certain "gateway" resources is essential to maintaining newcomers' access to the breadth of a community's resources.

As newcomers become full participants, their participation may help shape important aspects of the community. This can include shifting newcomers' access to gateway resources, a change that may facilitate or inhibit newcomers' participation. This poster discusses a case of a community of recreational cyclists. Cycling has recently been identified as a potentially rich area of interest for research in the learning sciences because it involves specialized knowledge and complex physical and social interactions that must be mastered (Lee, 2013; Hirsh & Levy, 2013; Taylor & Hall, 2013). In this study, we sought to understand how changes in a cycling community affected novices' access to a gateway resource.

## **The Focal Community of Recreational Cyclists**

Recreational group cycling involves individuals who are interested in learning how to ride long distances in groups. Beyond strength and endurance, group cycling requires riders to deal with various riding conditions (e.g., steep inclines, uneven terrain, changes in wind) while maintaining contact with the group. A gateway resource for group cycling is drafting, which involves riders following another rider closely enough to reduce aerodynamic drag. By drafting, new cyclists can ride with experienced cyclists, opening their horizons of observation (Hutchins, 1996) and allowing them to see the breadth of the experienced cyclists' practice.

This study involved an adult recreational cycling group from a mid-size city in the Intermountain Region of the United States. This group was established in 2006 by a bike shop with the goal of introducing beginners to the practices of group riding. This cycling group was one of many in its local vicinity but was widely known and recommended by cyclists throughout the region as one that was well suited for novice cyclists. Like many of the other local cycling groups, it met 1-2 times per week from Spring through Fall (the typical cycling season) for group rides ranging from 20 to 100 miles in distance.

## **Data Sources and Analysis**

The first author, a cyclist with seven years of experience riding in recreational groups, joined the focal group for a period of participant observation ranging from March through October 2013. He had no prior experience riding with the focal group and was positioned as a knowledgeable newcomer participating both as a rider and as an observer researching group dynamics and changes over time. During the period of observation, the cycling group had a core of 10 consistent riders and 40 other riders who participated less frequently. The group had roughly equal numbers of men and women, though the balance among participants varied from week to week.

The first author participated in and observed a primary group ride each week (i.e., a ride taking place regularly on a weeknight) and also participated in some secondary rides (i.e., taking place on a weekend on an ad hoc basis). Following each ride, he recorded written ethnographic field notes consistent with the recommendations of Emerson, Fretz, and Shaw (2011). He also obtained records from email lists and social networking sites associated with the cycling group. The collection of records and notes were coded by the first author following recommendations for qualitative data analysis from Saldaña (2012), then reviewed and discussed by both authors before the codes were refined, reapplied, and then reviewed for themes and patterns.

A second data source was a set of videorecorded interviews with 11 adult cyclists from the region. These interviews were collected two years prior to the observations for other research purposes (Lee & Drake, 2013) but were useful for a secondary analysis as they contained self-reports about prior experiences with the focal cycling group. In particular, these interviews included two novice female cyclists who were very articulate

about their prior experiences and were consistent attendees during the observed focal group rides. These two cyclists were treated as special cases for analysis given their continued participation in the focal cycling group.

## Findings

Based on interviews and from recorded conversations with cyclists during rides, the focal group was indeed initially a very welcoming group for novices. Specifically, experienced cyclists made a point to explicitly discuss drafting technique with newcomers. For example, when Stacy joined the group as a novice cyclist, she was resistant to learning drafting. She was not pushed to learn during her first ride, but on the second ride, the ride leader insisted that she could and needed to learn how to draft so she could keep up with the group. By the time of this study, Stacy had become a capable group cyclist and a leader in the group. Opportunities for learning how to draft were typically provided in the form of one-on-one, in-ride modeling of body and bike positioning for drafting.

However, the departure of some oldtimers coupled with the sustained participation of a different class of newcomers led to changes in practices of the group. These newcomers brought more aggressive riding goals and more athletic skill than did typical newcomers to this cycling group. The new class of newcomers regularly rode with the local race-oriented groups and were taking advantage of an additional group ride to add to their training regimen. With their riding skill and consistency, they quickly gained respect in the group. However, as group practices shifted to align with the goals of these newcomers, novices found it more difficult to join.

Although this group had always included riders of many skill levels, the strong and experienced riders had previously made conscious efforts to support the participation of novices through in-the-moment, explicit drafting instruction, like in the example described earlier, so that slower riders could at least “keep up.” However, as the rides sped up, supporting novices became less important even to the remaining oldtimers. For example, four months into the six-month riding season, a young, novice rider was struggling to stay with the group during a ride. An oldtimer observed that the newcomer struggled to keep up because he drafted poorly. Another rider commented to him, “Well, it’s your job to teach him.” To this, the oldtimer responded, “That’s not my job at all,” explicitly stating that the role of oldtimers as supporters of novices had indeed changed.

## Discussion

The purpose of this poster is to describe, through a case study, how changes in a community’s goals and practices can inhibit newcomers’ access to resources necessary for their peripheral participation. For the cyclists in this study, this resource was community-supported competence in drafting. Drafting allowed novices to interact with and observe the practices of individual oldtimers and the community as a whole. When maintaining novices’ access to drafting knowledge was no longer a priority, many novices were left without a means of joining the community and discontinued participation. Identifying such “gateway resources” and how they are maintained despite natural changes to a community of practice can help in understanding how a community may be more supportive of novice participants and support movement along pathways for learning.

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# **Examining Teacher Assignments and Student Work at the Intersection of Content and Practice in Middle School Science**

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**Abstract:** This poster presents two views of a year-long implementation of an NGSS-aligned curriculum including teachers' perspectives on challenges to provide opportunities for students to develop scientific practices and disciplinary content in tandem, and work produced by students as part of instruction. Initial findings that point to teacher tendency to use practices as an alternate student work product rather than as knowledge-generation activities are presented and discussed.

## **Introduction**

Development of the Next Generation Science Standards (NGSS; NRC, 2012) and Common Core State Standards formalizes a complex view of teaching and learning that calls for new models or curriculum design, pedagogy, and assessment that consider strategic integrations of multiple dimensions of learning. In particular, these standards reflect frameworks that recognize that learning occurs within disciplinary practices and that teaching, learning and assessment goals should reflect this complexity. Stakeholders at the many levels of the education system (teachers, administrators, state department leaders, etc.) must contend with the problem of redefining success, both in terms of instruction and student achievement.

This poster presents self-report data about teachers' instructional goals, their decisions and examples of their students' work produced as part of instructional activities collected over two years. This work was conducted in conjunction with an efficacy study of NGSS-aligned instructional materials and professional development. The *major issues* addressed by this poster are the challenges of developing and evidencing new views into teaching and student learning in a multi-dimensional instructional space. *Significant contributions of the work* include rich pictures of teacher understandings and instruction of NGSS aligned science materials and samples and analysis of student work as evidence of how students' understandings develop in NGSS-aligned instruction. The ICLS 2014 *conference theme* articulates the need to better understand learning through and embedded in disciplinary practices, making this work a direct response to the conference call.

This work takes place as part of an efficacy study of the Project-Based Inquiry Science (PBIS) curriculum, a comprehensive, 3-year middle school science curriculum that focuses on standards-based science content and uses project-based inquiry science units to help students learn. NSF funded the development of PBIS over the past two decades, with major investments made in the design of materials and with associated teacher professional development for teachers to understand the content of the units and how to teach them. PBIS materials and activities, though produced before the NGSS and its companion framework were developed, are designed to incorporate modeling, construction of explanations and other scientific practices as a way for students to construct understanding of phenomena in the context of long-term projects and investigation.

This poster will present two complementary views of a year long implementation of PBIS activities including 1) initial findings about teachers perspectives on how they provide opportunities for students to develop scientific practices and disciplinary content in tandem and 2) work produced by students as part of those activities over the course of the academic year.

## **Theoretical Approaches**

Classroom implementation is the lynchpin that will determine the impact of NGSS, as has been the case with past educational reforms (Fullan & Miles, 1992). Understanding the ways teachers may structure instructional activities, and understanding reasons for those choices, is necessary in order to evaluate how NGSS is impacting science learning. Specifically, exploring relationships between the kinds of instructional choices teachers are making and how those choices provide learning opportunities for students is a critical activity in examining and supporting implementation of NGSS (Henningsen & Stein, 1997). Professional development will need to be developed that can help teachers elicit and support student engagement in practices that integrate science concepts in meaningful ways. Moreover, teachers will need tools that will help them reflect on their instruction. This research is motivated by the need to further identify how the specific, strategic integrations of the disciplinary practices and core disciplinary ideas prioritized by NGSS support students' conceptual development along both dimensions, and how teachers might be supported to understand and elicit these processes. While the cross-cutting concepts are an essential dimension of NGSS, this work focuses on the integration of content and practices as an analytic starting point.

## **Methods**

This study takes place within a larger, two-year randomized-control (RCT) efficacy study of the PBIS materials. All 6<sup>th</sup> grade teachers of a large, diverse, urban school district were recruited to participate in the study. 42 middle schools with more than 100 sixth grade teachers are participating in the efficacy study. At the beginning of the study, schools in the district were randomly assigned to a study condition where PBIS would be used or a comparison group where current science curriculum materials would be used. Teachers in both conditions were invited to participate in professional development about the NGSS framework and practices. Teachers in the implementation group also were invited to participate in PBIS professional development.

35 teachers in each condition were recruited to participate in data collection to examine their assignments (TA) and the students' work (SW) produced as part of those activities; we refer to these data as TASW. Year one of the study occurred during the 2012-2013 school year and year two of the study is underway. While Year one data is being analyzed, producing preliminary findings presented here, both years of data will be available for presentation at the conference. All teachers were asked to provide information about classroom activities conducted to meet a set of 3 physical and 3 earth science state standards. This ensured a comparable data set across the two conditions and because the district uses a pacing guide, it was meant to ensure that data would be collected at about the same point in the year for all teachers. Teachers were asked to provide examples of work from students representing below average, average and above average performance across all their classes.

Classroom assignments were coded to characterize the ways modeling and construction of explanation, two important practices in NGSS are integrated and to characterize the ways the use of the practice aligns with NGSS definitions. Codes were compared with teacher descriptions of assignments. When possible, student work was analyzed according to rubrics developed by the project team anchored around NGSS performance expectations. When assignments did not align to NGSS performance expectations, student work was analyzed using rubrics developed as the as part of summative assessment design conducted by the team. Data integrity will be established using similar methods to Borko and colleagues (2005) via triangulation to classroom video tapes and teacher interviews. Borko et al (2005) showed that the use of teacher report of classroom activities, in conjunction with student work, can be a reliable method to characterize what goes on in classrooms.

## **Preliminary Findings**

Teachers who did not have the benefit of the PBIS curriculum were more likely to over estimate the role of the scientific practice in their assignments. These teachers were more likely assign activities that included modeling and explanation only as ways to describe phenomena rather than as a means to explore phenomena or to connect evidence and claims as part of explanations. Teachers who did not participate in professional development sessions were also more likely to assign activities where practices were not well integrated. Across conditions, students participating in these assignments, where modeling or explanation tend to be used as a means to help students identify components or elements of a situation or phenomenon, rather than as a means to make predictions or develop hypotheses, are less likely to show evidence of developing more complex understandings about the phenomena being studied. Further analysis will continue to explore these initial findings and relationships. Analyses of teacher reports will examine factors cited by teachers for instructional decision-making. Student work analyses will include comparisons of summative assessment data to contextualize student performances throughout the year.

## **Conclusions and Implications**

Initial results confirm the assumption that implementing NGSS will be a difficult transition for science teachers who appear to struggle with integrating modeling and explanation practices into their instruction in ways that provide students with opportunities to generate models or explanations that represent emerging reasoning. Implications of this work include a call for more research that can provide examples and point to challenges of implementation will be valuable to teachers and designers as NGSS is adopted across the nation.

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# **Examining the Use of Technology: Affordances and Constraints in a Blended Learning Environment**

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**Abstract:** Project-based learning environments that leverage technology have the potential to bring experts into classrooms, introduce youth to contemporary writing practices, and create avenues to participate in the information economy. This study focuses on the affordances and constraints within a blended learning environment for youth from two settings that both claimed to be one-to-one laptop schools. Preliminary findings show students were caught in the digital divide because of their school's definitions of appropriate technology use.

## **Proponents of Connected Learning**

A blended learning environment seeks to bring together the best of the classroom and the affordances of technology integration. This study explores the student experiences of blended learning environments at Ruby and Sapphire, which were both one-to-one laptop schools engaging in a six-week project-based curriculum. The phenomenon of the digital divide intersects with the notion of being a one-to-one laptop school especially when learners encounter barriers to participation.

## **Challenges and Affordances of Blended Learning Environments**

With this analysis, we hope to draw attention to the affordances and constraints of blended learning environments in one-to-one laptop schools and to highlight the ways in which learning context and structure matter. We propose that the students in the schools were caught up in the digital divide because of their school's definitions of appropriate technology use and the ways that the schools were equipped to support teachers and students use of technology.

Ruby was a large comprehensive public high school serving over 2000 students. Demographics from the 2010-2011 school year, the most recent data available on the school website, show that the school population was 27% White and 73% Students of color from a wide variety of ethnic backgrounds. There was also a large free and reduced lunch and ELL population. Ruby's district was in the beginning stages of a one-to-one laptop program at the school, which assigned a laptop to each incoming ninth grader. Teachers were also equipped laptops and Smart Boards in their classrooms.

Sapphire, the second context, was a girls-only independent school serving 100 young women in grades five through eight. Although it was located in a diverse neighborhood near the center of the city it served a relatively upscale student population with 35% students of color. They had a commitment to providing 30% of their student body with need-based financial aid. The school offered students a large degree of autonomy, trust, and responsibility. Sapphire does not give grades instead teachers write narratives that describe student's strengths, weaknesses, areas for improvement, and chart their participation in class projects over the course of the quarter.

We collected data from both schools during the implementation of a project-based learning unit designed for the English language arts classroom as part of a larger research study. The unit incorporates technology to cultivate thriving social networks and leverages video, disciplinary tools to help youth progress along competency pathways, the use of experts to provide feedback to students for multi-faceted learning supports, and positions students with multiple ways of expression. Materials for the six-week unit were loaded into a platform called Canvas, which students and teachers accessed on a daily basis.

## **Theoretical and Methodological Approaches Pursued**

We viewed the classroom as an activity system with various components interacting with one another. Yorjo Engeström (2008) generated activity theory to represent how learning is a process driven by tensions and contradictions within an activity system. The system is composed of a number of components utilized by an individual or a group working towards a shared object to obtain a desired outcome. Cultural historical activity theory (CHAT) stems from Vygotsky's activity theory where "human behavior results from the integration of socially and culturally constructed forms of mediation into human activity" (Lantolf, 2000, p.8). CHAT highlights the development of various components such as tools, division of labor, goals, outcomes, subjects, rules, and community to understand an activity system and the activities that occur within the system. We employed CHAT to represent the classroom-learning environment and the challenges and affordances for students with regards to the technology used within the PBL space. The components of the system represented by Engeström triangle are subjects, tools, rules, community, division of labor, objectives, and outcomes. We will show the mapping of each classroom setting using these elements to highlight the affordances and

constraints for students. The data sources in the analysis include video recordings of the classroom during the implementation, focus groups with students after the completion of the unit, teacher interviews, and field notes of daily classroom interactions with students.

## Preliminary Findings and Implications

This comparison between research context is not intended to establish a deficit framing for the students or teachers at the comprehensive high school or set them in direct competition with the outcomes at the independent high school rather we seek to compare the activity systems surrounding both implementation contexts. Our intent is to highlight the ways in which the tools, rules, community, division of labor, had an impact on the objectives, and outcomes in each context. These findings suggest the need for new implementation strategies for blended learning environment designers, the design of curriculum, as well as choice of educational technology platforms that lead to sustainability of use amongst all student populations.

We noticed vast differences in technological literacy, school infrastructure and teacher familiarity which all had an impact on students' experience of the blended learning environment in the classroom. We also noticed that the schools had different expectations of classroom regulation and the purposes for technology in the classroom.

At Ruby, the PBL unit was the very first unit of the year. We started working with students during the second week of their ninth grade year. We worked with a single teacher, Ms. Prince, who had three sections of Fundamentals classes. There were 20-23 (total 63) students in each class from a variety of linguistic and cultural backgrounds. Ms. Prince was very motivated to do this curriculum with her students. She saw the collaboration with our program as an opportunity to develop her technology implementation skills. She was particularly interested in working with the SMART board and students laptops more effectively. She bemoaned the fact that her school had very little support for teachers who wanted to learn about blended learning environments.

The students at Ruby were assigned a laptop at the beginning of the year, however, the integration of technology was a challenge for the teachers and the staff. The students' school emails could only reach other students, teachers, and staff within the school and did not connect to the outside world. Many of the students left their laptops in their lockers overnight. And while the students were tech savvy with utilizing technology for non-academic purposes, they were inexperienced with the use of technology connected with academic learning. We attributed this lack of familiarity with the school's insufficient facilitation of the use of technology.

Our collaborating teachers Ms. Fenrich and Ms. Archer at Sapphire were used to designing interdisciplinary project-based units and working with a mixed specialty team. We worked with the entire eighth grade, 35 students total who were divided into two groups called cores.

The students at Sapphire were high functioning and autonomous in their academic endeavors and were focused on applying to high school at the end of their fall quarter when we were there. Sapphire was also a one-to-one laptop school that provided every student with an Apple MacBook Pro. The students were not allowed to bring their computers home, however, most if not all had access to technology at home. Because they were familiar with technology use in academic settings, the students were at ease with accessing the platform to download materials, conduct online research and reviewing websites, and exchange messages with the experts.

Given our experiences in these vastly different implementation contexts, we would advocate for the design of a mobile application as a platform that could be more sustainable across our study population. Literature on the digital divide can foreground the ways in which certain segments of the population have restricted access to computers and other technologies, whereas this study explores the larger activity systems necessary to support teachers and students' use of computers in sustainable ways.

## Relevance To Conference Theme

Our study is connected with the conference theme "Learning and Becoming in Practice" because we are contributing to the body of literature that examines learning environments that foster disciplinary engagement with technology. We compare the curriculum implementation of the same unit in two different settings with specific focus on the technology use of teachers and students. Our students are positioned in the environment to become digital experts but experience challenges due to the school structure.

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# **Demystifying Success in a Summer Bridge Program: Investigating Students' Intrinsic Motivation and Mastery Goals in the Context of a Learning Analytics Intervention**

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**Abstract:** This study investigated students' academic motivation orientations in a summer bridge program and how a learning analytics-based intervention supported the activities of the academic advisors. Students' mastery orientation decreased over the course of the term and our results showed how certain learning analytics features and use cases were associated with this change. The findings indicate that student motivations need to be carefully considered in the design of learning analytics-based interventions since the resulting tools can affect how students make sense of and engage with their courses.

## **Introduction**

Postsecondary institutions need viable and successful models to increase retention, particularly for those groups of students with historically lower graduation rates. As learning analytics (LA) tools have been utilized to address retention concerns, students' pre-entry attributes and their formal institutional outcomes (i.e., grades) have dominated the predictive models that drive these interventions. Students' intrinsic motivation to achieve their stated goals and their capacity to plan and utilize available resources are fundamentally linked to retention in higher education, yet these measures are difficult to include in large-scale LA tools. This study investigated students' motivational orientations and how a LA-based intervention supported the activities of the academic advisors by asking the following research questions:

- RQ1: How do students' motivational orientations change during a summer bridge program?
- RQ2: What factors are associated with changes in motivation during a summer bridge program?
- RQ 3: What is the relationship between when advisors' use an early warning system and their students' academic performance during a summer bridge program?

## **Theoretical Framework**

Existing theory has shown how students' motivation within the context of competence-relevant activities can be defined as achievement goals, converging in mastery and performance goals. "Mastery goals focus on the development of competence and task mastery, whereas performance goals focus on the demonstration of competence relative to others" (Rawsthorne & Elliot, 1999, p. 326). Performance goals may be further delineated into performance-avoid and performance-approach orientations (Elliot & McGregor, 2001). Achievement Goal Theory posits that students engage with learning environments differently based on these orientations (Dweck, 1986).

## **Methodology**

Our research agenda is organized around principles of design-based research. We collaborated closely with the leaders and staff of a summer bridge program to design and implement teaching methodologies, student surveys, and a learning analytics-powered early warning system intended for academic advisors.

## **Setting, Participants, and Data Sources**

This study focuses on the seven-week Summer Bridge Program ("Bridge") that is situated within a large four-year, more selective, lower transfer-in, and primarily residential university with very high research activity (<http://classifications.carnegiefoundation.org>) located in the Midwestern United States. Two hundred and sixteen Bridge students completed three courses in the Summer 2013 term. Most participants were female (62.5%) and identified as members of an underrepresented minority group (69.4%). One-fifth (21.8%) were first-generation college students and one-sixth (14.8%) were athletes. Students' high school GPAs ranged from 2.1 to 4.0 ( $M=3.45$ ) and composite ACT scores ranged from 14 to 30 ( $M=22.54$ ).

Two online motivational surveys were distributed, one at the start-of-term (12 items) and one at the end-of-term (22 items). To measure students' motivational orientations, selected items from the Patterns of Adaptive Learning Scales (PALS) instrument were employed in both surveys. While the surveys represent the main data sources, the overall project was focused primarily on how academic advisors in Bridge used an early warning system (EWS), Student Explorer, which was designed to provide advisors information about their students' performance to facilitate timely interventions (see Krumm, Waddington, Lonn & Teasley, in press).

## Results

Paired-samples *t*-tests assessed whether students' goal-orientations changed during Bridge (RQ1). There were no significant differences between pre-bridge and post-bridge performance-approach scores or performance-avoid scores. There was a statistically significant decrease in students' pre-bridge mastery scores ( $M = 4.7$ ,  $SD = .55$ ,  $\alpha = .89$ ) and post-bridge pre-bridge mastery scores ( $M = 4.3$ ,  $SD = .84$ ,  $\alpha = .93$ ); ( $t(208) = 6.53$ ,  $p < .001$ ).

To better understand what might contribute to this decrease in mastery orientations (RQ2), we specified a multiple regression model of students' change in mastery. We controlled for relevant demographic characteristics, previous academic expectations and support, incoming mastery, as well as previous achievement. Students' incoming mastery was positively associated with their outgoing mastery,  $\beta = .34$ ,  $t(12) = 3.1$ ,  $p < .01$ . Surprisingly, students' self-reports of how often their advisors showed them their EWS data were *negatively* associated with changes in mastery  $\beta = -.11$ ,  $t(12) = -2.247$ ,  $p < .05$ , ( $R^2 = .30$ ,  $F(12) = 6.12$ ,  $p < .01$ ).

Since Bridge programs are meant to ensure that students are prepared for college-level coursework, we wanted to understand which factors were associated with student's final grades. Using multiple regression models, we controlled for demographic characteristics, academic achievement measures, high school preparation, and encouragement by family and friends. Athletic status was negatively associated with English course grades,  $\beta = -.67$ ,  $t(15) = 2.52$ ,  $p < .05$ , while students' reports of excellent high school teachers were positively associated with English course grades,  $\beta = .12$ ,  $t(15) = 2.04$ ,  $p < .05$ ,  $R^2 = .31$ ,  $F(15) = 2.83$ ,  $p < .01$ . For students in the remedial Math course (A), mastery orientation was *negatively* associated with course grade,  $\beta = -.67$ ,  $t(16) = 2.52$ ,  $p < .05$ , and the Bridge advisors EWS views *after* meeting with students was also negatively associated with students' Math A course grades,  $\beta = -13.4$ ,  $t(16) = -2.952$ ,  $p < .05$ ,  $F(16) = 11.11$ ,  $p < .001$ . For students in the college-level Math course (B), perceived family encouragement was negatively associated with course outcomes  $\beta = -15.6$ ,  $t(17) = -2.15$ ,  $p < .05$ ,  $F(15) = 5.18$ ,  $p < .001$ . Finally, students' self-reports of how often their advisors showed them EWS data were not associated with any course grade.

## Discussion and Conclusion

While Achievement Goal Theory research has shown that high mastery orientation is adaptive for students in academic settings (Rawsthorne & Elliot, 1999), our results show that some features of the Bridge program may moderately decrease students' mastery goal orientations (RQ1). We were surprised to learn that showing students their own data within the context of an early warning system (EWS) might have contributed to this decrease (RQ2). Yet, we do not know *which* features of EWSs contribute to this decrease. Moreover, our findings support the idea that any student-facing LA intervention will need to be developed and deployed with care, because such tools affect how students make sense of and engage with their courses.

Understanding the relationship between when advisors used the EWS and students' academic performance as measured by course grades (RQ3) is a nuanced endeavor with mixed results. After controlling for pre-entry demographics, students' perceptions about encouragement from family and friends, and formative course performance, the extent to which Bridge advisors viewed students' data via Student Explorer *after* meeting with students was negatively associated with students' Math A course grades. One of the limitations of our study is that, by design, EWSs encourage deeper investigation of students who are struggling academically than students who are thriving, thus skewing the statistics gathered from EWS user actions. A student with a lower grade is therefore more likely to have their advisor log EWS use than a student with a higher grade, potentially explaining the trends witnessed in our analyses.

LA interventions are designed to foster optimization of learning and learning environments that could ultimately improve student performance and retention. Our results indicate that even guided presentations of student performance data can have significant effects on students' academic achievement and their motivational orientation. Therefore, designers of LA interventions should consider how best to collect and present such data sources. Furthermore, the next generation of LA interventions must resolve the tension between ease of scalability in current data sources (e.g., grades) and the richness of measures such as students' intentionality, goals, and motivations that have proven utility in tailoring learning environments to learners' needs, but are more difficult to collect at scale and integrate into current LA tools and processes.

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# Designing Collaborative Learning Activities for Two Outcomes: Deep Structural Knowledge and Idea Generation

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**Abstract:** Four versions of a collaborative activity were designed by manipulating two factors: cognitive engagement and preparation to collaborate. The activities were implemented in real classrooms where students worked in pairs. Findings showed a benefit of preparation on deep knowledge, regardless of how students were instructed to engage. However, discourse data revealed that only students in the “constructive” engagement conditions generated ideas beyond the target concepts. The implications for classroom practices are discussed.

## Introduction and Purpose

To extend the work on the Interactive-Constructive-Active-Passive (ICAP) framework and the Preparation for Future Learning (PFL) paradigm, this work drew from the theoretical assumptions of each model to investigate how a collaborative learning activity implemented in introductory psychology courses at a community college would impact deep understanding of concepts of memory. Both models support the notion that students will be more likely to acquire structural understanding of a topic (i.e. build more accurate mental models) when they have the opportunity to struggle with existing knowledge because it allows them to fill gaps and resolve inconsistencies in thinking (Chi, 2000; Schwartz, Sears, & Chang, 2007).

The ICAP framework differentiates how student overt behaviors link to underlying cognitive processes (Chi, 2009; Menekse, Stump, Krause, & Chi, 2013). For example listening to a lecture constitutes *Passive* engagement and aligns to the process of *storing knowledge*. Copying a teacher’s notes from the board during the lecture makes engagement *Active*, linked to *assimilating knowledge*. To be categorized as *Constructive* engagement, students would have to *create knowledge* such as through generating explanations or questions in their own words. *Interactive* engagement links to *co-creating knowledge*, where discussion would lead to shared meaning. Since we know that students do not always interact effectively nor engage in dialogic behaviors that facilitate mutual meaning-making (Barron, 2003; Volet, Summers, & Thurman, 2009), researchers continue to search for ways to improve collaborative activities. The current study aimed to address whether collaborating on a *constructive* version of a task compared to an *active* version would improve student interactions to lead to deeper learning. In other words, would a task designed specifically to elicit *constructive* cognitive engagement help students to collaborate more effectively for learning?

The PFL paradigm offers a dual phase instructional model where students first “prepare” their knowledge through a difficult open-ended learning activity, and then consolidate knowledge through a “future” lecture (Schwartz & Bransford, 1998; Schwartz & Martin, 2004). For the current study, the same premise was used to create a collaborative task that could provide a preparation-of-knowledge period and a consolidation-of-knowledge period. In this case, students first worked on the task alone to prepare knowledge, then completed the task with a partner to consolidate knowledge through discussion. This aimed to address the question of how collaboration, rather than a form of direct instruction, could serve in the consolidation phase of a PFL model. Thus, by using ICAP and PFL as instructional design tools, this work aimed to create a collaborative task that could present the opportunity to struggle with knowledge through *constructive* engagement during “preparation,” and then to consolidate knowledge during “future” collaboration to lead to deep learning.

## Methods

The study used an experimental design in authentic classroom settings, preserving internal validity by equally representing all conditions in each classroom and randomly assigning students to conditions and partners ( $N=90$ ). It occurred over the course of one week and included a pretest to assess prior knowledge, the learning activity, and a posttest to assess structural knowledge. The students participated in the study as part of their regular curriculum, with the study activities replacing the instructors’ original instruction for the topic of Memory. The learning materials were equivalent in content and time-on-task was equalized across conditions. The four conditions were as follows: Prep/Constructive, Prep/Active, No Prep/Constructive, No Prep/Active. In the Prep conditions, students worked on the task alone for part of the class and then completed the task with a partner. In the No Prep conditions, students worked jointly the entire time. In the Constructive conditions, students were asked to invent concepts after examining data from real-world experiment scenarios. In the Active conditions, students were given the concepts to study and then asked to apply them to the (same) real-world scenarios. Structural knowledge was measured by a posttest that required students to predict the results of new experiments based on the target concepts of the learning activity. Student work was scored using a rubric that was developed *a priori*. For a secondary analysis, a subset of student pairs were audio-recorded during the activity ( $N=15$ ). These data were used to examine the ideas students generated throughout discussion.

Utterances were segmented and coded by content to separate single and distinct idea units (Chi, 1997). The number of target concepts and novel concepts (i.e. those not embedded in the learning materials) were recorded.

## Results and Interpretations

A dyadic analytic technique was used to account for subject dependency to evaluate the structural knowledge outcomes. Contrary to the hypothesis that there would be an advantage of the *constructive* version of the task, students in both Prep conditions equally outperformed the No Prep groups by approximately a letter grade,  $F(1,41.1)=5.79$ ,  $p<.03$ . Thus, it appears that collaboration can sufficiently replace lecture as a “future” task (with regard to PFL) but that the preparation need not be *constructive* (with regard to ICAP). However, there was an observable benefit of the *constructive* version of the task in the discourse data; only the pairs in the *constructive* conditions generated any novel ideas beyond the target concepts. Thus, the added benefit of interacting on a *constructive* compared to an *active* collaborative task that also includes a preparation period is that students are able to generate new ideas without impairing targeted learning. Findings are summarized below.

**Table 1: Comparison of outcomes: deep knowledge and discussion of target versus novel concepts**

	Posttest	Discourse	
Measured:	<u>Deep knowledge</u>	<u>Target concepts</u>	<u>Novel concepts</u>
Occurred:	After learning activity	During learning activity	During learning activity
Completed:	Individually	Collaboratively	Collaboratively
Instructional Conditions			
Prep/Constructive	$M = 75.00$	$M = 3.25$	$M = 3.50$
Prep/Active	$M = 76.17$	$M = 7.33$	$M = .0$
No Prep/Constructive	$M = 66.67$	$M = 4.00$	$M = 4.50$
No Prep/Active	$M = 61.17$	$M = 6.75$	$M = .50$
Total possible	100%	8 concepts	N/A
N	90 students	15 pairs	15 pairs

## Discussion

This work tested four versions of a collaborative learning activity implemented in authentic classrooms to inform on the usability of combining two cognitive frameworks for instructional design. It extended the PFL model to show that preparation as individual work followed by collaboration as a future task can benefit deep learning. Future work will examine how collaboration compares to direct instruction in the consolidation phase. Although no differences in deep learning were detected between the *active* versus *constructive* tasks, this work expanded upon the ICAP framework to show that collaborating on *constructive* tasks leads students to generate novel ideas during discussion, whereas collaborating on *active* tasks limits discussion to the concepts explicitly stated in the learning materials. With regard to instructional practice, teachers can use these two cognitive frameworks together to design collaborative learning activities that both improve deep knowledge and facilitate idea generation during discussion.

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# Promoting Diversity within the Maker Movement in Schools: New Assessments and Preliminary Results

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**Abstract:** In recent years, FabLabs and Makerspaces have opened all over the globe, including in schools. However, notwithstanding the popularity of this movement, its track record with diverse populations is still dismal. In this work, we discuss a pedagogical framework for a more inclusive “maker movement” and show results from the creation of new assessments for such environments.

## Introduction

In recent years, laser cutters and 3D printers have dramatically dropped in price, and open source hardware has popularized these technologies. FabLabs have opened all over the globe (Gershenfeld, 2007; Mikhak et al., 2002), the MAKE Magazine was created, and soon after the Maker Faire was established, and now several schools have their own labs (Blikstein, 2013): the Maker Movement is upon us. But despite its popularity, the maker movement and FabLabs carried with them the culture of its creators: high-end engineers (from the FabLab community) and publishers (from the MAKE Magazine). These professional cultures did not have a tradition of working in diverse schools. FabLabs were designed for expert hackers, and the “make” publications catered to a “teenage hacker” subculture overwhelmingly dominated by suburban white males with abundant resources (Buechley, 2013), characterized by a strong self-selection of elite students into autodidactic and relatively closed communities. Despite the fact that the “maker” movement went much beyond its origins, these roots influenced its modus operandi until these days: Buechley (2013) showed that since its inception, 90% of the covers of the MAKE Magazine have had white males on them, and 70% of the projects were cars or robots. When considering the expansion of this movement to public education there is an urgent need to consider diversity as a crucial component, as well as how the movement would fit into non-dominant cultures and context (Lee, Spencer, & Harpalani, 2003).

In previous work (Blikstein, 2008) we discussed how many of the projects proposed in maker workshops are irrelevant to the culture of diverse learners. In this paper, we will focus on the issue of diversity and cultural relevance, and comment on two studies that touch on these issues. Given the space limitations, we will only present a summary of the results. In a pilot study, we ran a survey instrument for approximately 400 students in two schools (one high SES, 10% minority, and one low SES, 99% minority). The survey’s goal was to find differences in how students would engage in “maker” activities. The data showed that in both schools, students had a similar level of unfamiliarity with programming and robotics (both schools had 2.4 for programming and 1.7 for robotics on a 1-6 scale, “6” being “very familiar”). However, a significant difference appeared in the questions that were probing psychological constructs. Students in the high-SES school were more likely to say that they “had a good imagination” (5.1 vs. 4.7,  $p < 0.001$ ), that intelligence is a malleable entity that can be changed (4.8 vs. 4.0,  $p < 0.001$ ), and that they have had at least one idea for an invention (45% vs. 20%,  $p < 0.01$ ). These and other survey results show that these two populations would engage very differently in activities characterized by autodidactism and in which self-efficacy play a significant role. Based on these data, we set out to develop a research-based curriculum for a maker workshop that would address—and potentially reduce—those differences. We started with ethnographic research in the schools, and realized that in the low-SES school, students would often report that they used to ‘make’ and build things with their parents and friends, and often had jobs in garages or carpentry shops: *these students were already makers, but were not aware of it*. Thus, we designed a curriculum to re-value familiar practices drawn from students’ funds of knowledge, rather than replace existing ones (Freire, 1974; Moll, Amanti, Neff, & González, 1992). Students brought familiar practices to the lab (craft, carpentry), and they got augmented using socially-valued skills such as computation, fabrication, and mathematics.

To evaluate the results of this intervention, we developed many instruments for measuring the effectiveness of the curriculum, especially in terms of its reach to diverse populations. For example, we developed a test called “logic flow,” in which students had to create a block diagram with computer pseudo-code describing the functioning of everyday objects. We administered this test before and after the workshop to a group of 15 students. Our coding scheme had eight dimensions of complexity and completeness of these logic flows. The results showed that while students from all expertise groups improved, the bottom third of the class improved almost twice as much as the top third, considering the medians, thus reducing the gap in computational knowledge between the students with high (typically white males) and low (typically minorities) previous knowledge about computer programming and making.

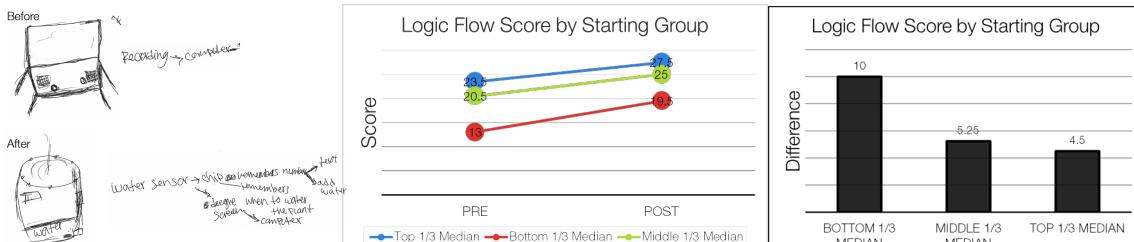


Figure 1. An example of a pre-post “Logic Flow” (left), and the results by starting group (right)

A second instrument that we developed was the “maker table:” students would write and draw all steps of a fabrication process, along with their confidence in their ability to perform each step. Again, we administered the test before and after the workshop, and the results were quite positive in terms of reducing inequality (see Figure 2). Not only did the scores improve equally for both boys and girls, but the gain as measured by the median of both groups overwhelmingly favored girls: while the improvement for boys was of one point, girls improves 3.4 median points from the beginning until the end of the workshop.

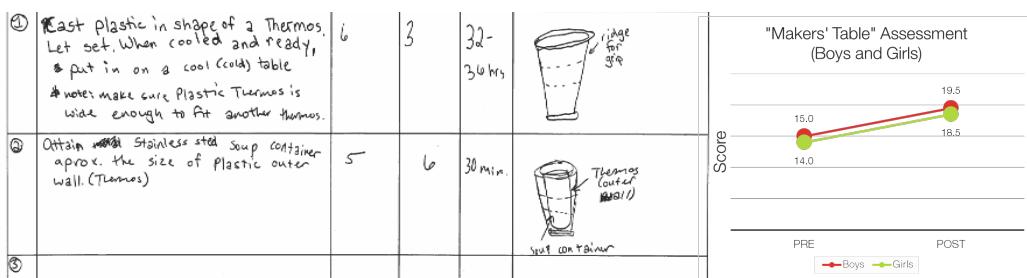


Figure 2. The “Maker’s Table” (left) and the pre-post results (right)

These preliminary results point to (1) the great inequality in high- and low-SES schools in how students consume the “maker” movement, (2) the possibility and need of designing curricula to disproportionately benefit low-SES students, (3) the fact that improvement in these open-ended environments can be measured by customized instruments. Despite the potential of digital fabrication labs and ‘making’ in education, educators and scholars must remember that the real power of this movement is in its potential to reduce rather than amplify inequality, and that researchers have a crucial role in raising awareness to diversity, culturally-aware curricula, and new research methodologies for studying these environments.

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# **Talk as a Window into Collaborative Lesson Design: Designing a Common Rubric in an Elementary School Work Circle**

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**Abstract:** This poster aims to illustrate the analytic value of a design conversation that occurred during a multi-year practitioner-researcher partnership. This partnership takes the form of work circles (Fogleman, Fishman, & Krajcik, 2006; Reiser et al., 2000; Shrader et al., 1999; Shrader et al., 2001), which are a participatory, collaborative design setting. We present an example of how a dialogue between elementary teachers and university researchers offers a window into the design process and design itself.

## **Introduction**

This poster aims to illustrate the analytic value of a design conversation that occurred during a multi-year practitioner-researcher partnership. This partnership takes the form of work circles (Fogleman, Fishman, & Krajcik, 2006; Reiser et al., 2000; Shrader et al., 1999; Shrader et al., 2001), which are a participatory, collaborative design setting. The work is participatory in that it engages practitioners as central to the design and research process (Schuler & Namioka, 1993). In the case of work circles, researchers and practitioners collaborate to analyze and set goals related to a problem of practice, and to design instructional materials that address an identified goal. Decision-making in the work circle is democratic (Shrader et al., 1999). However, external funding, policies, and other factors may set parameters for the work content, timelines, and products.

The current practitioner-researcher partnership focuses on improving the quality of student writing across the content areas. These work circles aim to improve students' ability to make evidence-based claims in their written work. To achieve this goal, the work circle teams: 1) create, share, and provide feedback on lessons related to claims and evidence; 2) design common assessments of student writing; and 3) iteratively refine instructional resources and the design process.

## **Theoretical Approach**

The work circle reflects a distributed intelligence framework (Pea, 1993), which posits that intelligence is created and distributed in interaction and artifacts across an activity in relation to a goal. Knowledge about teaching and learning is shared through the participants' interaction within the work circle in relation to the set problem of practice. The design process should recognize and draw on the expertise of each participant. Although participants might not participate equally at each stage of the process, all do contribute to the work at different points in the collaboration.

In a work circle, there are two levels at which to consider learning – that of the participants, and that of students. The instructional resources that the group designs are intended to share targeted knowledge with students. We suggest that the work circle participants, both researchers and practitioners, learn through the process of designing and revising instructional resources for students. It is through the participants' negotiation of what to include, what not to include, and what to adapt in a lesson that the group gains a greater understanding of the learning task. Through an analysis of the work circle meetings, we seek to understand how the design conversations draw upon knowledge about practice, as well as how that knowledge is reflected in the artifacts that the participants create.

## **Methodological Approach**

The current analysis focuses on one work circle, which was comprised of eight teachers from a laboratory elementary school, a researcher, and a graduate student researcher. The group collectively determined the problem of practice to address, and the design goals related to this problem of practice, as well as when, and how often, the work circle meetings occurred during the school year. This work circle began meeting in fall 2012, and convened approximately 1-2 times per month throughout the 2012-2013 school year. These meetings occurred on site during the school day. Each work circle meeting was approximately 1 hour. There were a total of 15 work circle meetings.

During the first work circle meeting, the participants considered problems of practice that would be meaningful for the group to address. The group identified a need to create shared tools and language for teaching students to make evidence-based claims across the content areas. Over the course of the school year, the work circle designed and refined lessons, tasks, and a rubric related to this goal. The group would coordinate instruction and collaboratively plan lessons during the work circle meetings, the teacher partners would enact these lessons in the classroom, and then the group would discuss the lessons and learn from the resultant student

work. In order to document the design process, the researchers audio recorded and then transcribed each of the work circle meetings. The researchers also took notes during the meetings, and collected copies of lesson plans, rubrics, and other instructional resources that were discussed or created during a meeting.

This analysis sought to examine “decision points” in the work circle design conversations. We reviewed meeting transcripts to identify portions of a meeting during which the researchers and teachers discussed a particular topic related to a lesson or other instructional resource. We identified the point when a participant, or participants, first introduced an idea in the conversation, and then determined when the group arrived at an agreement within the meeting. However, the topic may have been revisited in a subsequent meeting. These segments range in the amount of dialogue that they include. The segment described in the next section was identified as a decision point in the design of a rubric for evaluating student work. It is representative of several segments that occurred over the course of design meetings related to this rubric.

## Preliminary Analysis

In this “decision point” segment, the work circle team members are engaged in the design of a rubric for evaluating claims and evidence in student writing. This moment of design discussion emerged at a midpoint during the school year. In previous work circle meetings, the group had decided that it was possible to analyze students’ claims and evidence work across the content areas, and that it would be useful to design a common rubric that could be applied to student work. The group also determined that claims and evidence could be analyzed according to three criteria: accuracy, relevance, and depth. In this segment of conversation, the group worked to reconcile a description of accuracy in the rubric. However, this conversation was not simply wordsmithing. As the participants designed the rubric, they engaged in questions around the kinds of knowledge they wanted to have about students’ ability to make claims and offer evidence. In probing the wording related to the accuracy of claims, the participants tacitly and explicitly drew on the knowledge present in the group. They identified potential redundancy in the knowledge that would be derived from two statements on the rubric. They read the statements aloud, and wondered about the differences between relevance and accuracy. They identified likely points of confusion in the rubric, and they decided to annotate the document so that students would not be confused. The researcher role was to seek clarity about the wording, and to offer recollection of previous ideas that were part of earlier instantiations of the design.

## Discussion

The theme of the 2014 ICLS conference is “Learning and Becoming in Practice.” In this poster, we present an example of how a dialogue between elementary teachers and university researchers offers a window into the design process and design itself. We have suggested that participant talk, within the context of a collaborative practitioner-researcher design context, helps us to recognize what teachers “call out” as important in a designed artifact, as well as how teachers and researchers make knowledge claims, resolve differences in recollection and in knowledge, and interact with each other to refine designs. In future explorations of talk in collaborative design contexts, we hope to offer additional evidence of how participants’ knowledge claims and expertise come to bear on the design of common artifacts.

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# **What Is and Who Can Do Science? Supporting Practice-Linked Identities in Science for Racially/Ethnically Underrepresented Youth**

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**Abstract.** This study examines the development of students' science and racial identities during summer science research programs. I utilize qualitative and quantitative data sources to examine students' incoming ideas about *what* science is and *who* can do science, how these ideas shift while participating in scientific practices, and program resources that support these shifts. Findings show that ideas about *what* and *who* shift together and unique resources support the co-construction of students' science and racial identities.

## **Introduction**

The issue of racial/ethnic underrepresentation in science (Oakes, Ormseth, Bell & Camp 1990) is complicated by dominant representations of *what* science is and *who* can do science. These representations provide narrow images of science (e.g. prescribed labs) and scientists (e.g. white, male) that are problematic for students from diverse backgrounds. A typical solution to increasing diversity in science is through instructional and policy reforms (i.e. focusing on *what* science is), yet racially-based achievement gaps are persistent (National Science Board, 2012). In order to dismantle persistent issues of equity, equal attention must be paid to the messages youth of color receive in science contexts about *who* can do science.

## **Objective**

This study examines trajectories of developing interest in, and identification with science for high school students of color as they participate in summer science research programs designed for racially/ethnically underrepresented youth. Students conduct investigations alongside scientist mentors as part of the programs. I explore science identity in relation to racial/ethnic identity to examine how ideas about *what* science is and *who* can do science develop together through participation in the practices of science. I ask three questions:

- What are racially/ethnically underrepresented students' incoming ideas about *who* does/can do science?
- How does conducting research alongside scientist mentors inform students' views of *what* science is?
- How do program resources support shifts in students' ideas about *what* science is and *who* can do science?

## **Potential Significance of Work**

Though research shows that racial positioning matters for women of color's long-term science trajectories (e.g. Carbone & Johnson, 2007; Malone & Barabino, 2008), treatments of race in relation to science are limited. New theoretical frameworks are needed that consider relationships between science learning and multiple aspects of identity construction (racial, disciplinary, academic) (Varelas, Martin, Kane, 2012). This research provides empirical evidence for how students' racial and science identities develop together in science contexts and the types of program resources that support shifts in students' ideas about what science *is* and *who* can do science.

## **Theoretical Framework**

I draw on socio-cultural theories of learning and identity (Wenger, 1998). I view identities as fluid, dynamic and socially constructed from the resources available (Holland et.al.,1998) as students are positioned and position themselves in science learning environments (Harre, 2008). Science identity literature offers insights into the types of identities offered to underrepresented youth (e.g. Polman & Miller, 2010; Tan & Calabrese Barton, 2010), yet research that examines how youth of color negotiate their racial positioning in relation to science is limited (Rahm, 2007). I utilize the "practice-linked identity" framework (viewing participation in a practice as integral to who one is) and its supporting identity constructing resources (material, relational, ideational) (Nasir & Cooks, 2009; Nasir, 2012) in order to explore *how* learning, positioning, engagement, and connection to science develop *in context*.

## **Overview of Methods**

*Programs.* The three summer science programs involved in this study contrasted in two main ways: 1) program content: race/diversity explicit (directly addresses race/diversity) vs. race/diversity implicit, and 2) science investigation content: community-based (e.g. environmental science) or traditional (e.g. physics). *Participants.*

1) Students: grades 9-12, Northern California high schools, 2) Mentors: science instructors, science graduate students. *Data Sources*. 1) Pre/post student surveys; 2) Pre/post student content assessments; 3) Semi-structured interviews: a) student interviews (pre/post, 6 focal students/program), b) scientist mentors; 4) Program observations.

## Findings

Analyses show that students' incoming ideas about *who* does science are often shaped by stereotypical images of scientists (e.g. white, male, lab coats) and science practices (e.g. mixing chemicals). As a result, students often see their own racial background and experiences as discontinuous with scientists. This informs students' sense making regarding racial/ethnic underrepresentation in science in ways that often places blame on the individual or ones' culture/racial group. Findings show that students' ideas about *what* science is (e.g. practices) and *who* can do science shift together while participating in the practices of science. Conducting research alongside scientist mentors broadens students' views of what counts as science, and allows students to identify as capable science learners. In addition, different practices (e.g. presenting research) serve different identity functions for students impacting how they see themselves in relation to science. Some program resources utilized by instructors/mentors support holistic (science and racial) identity construction. Instructors who employed a racially conscious lens made unique resources available that supported the co-development of students' science and racial identities. Findings from this research illuminate program resources that increase students' understanding of and ability to take up the practices of science and create opportunities that allow for shifts in students' ideas of *who* can do science.

## Conclusions and Implications

This research challenges and extends our understanding of scientific practices that can be leveraged in science programs and classrooms to create more authentic experiences and broaden opportunities for participation in science. Likewise, this research illuminates program resources that allow students to negotiate their racial/ethnic identities and positioning in relation to science and create opportunities for shifts in their ideas of *who* can do science. Together these findings can inform the design of learning environments that create multiple pathways for learning and identification in science and better support practice-linked identities in science for all learners.

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# **Workshops**



# **Current Research and Practice on Learning Communities: What We Know, What are the Issues, and Where are We Going?**

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**Abstract:** We envision building an ongoing, international research collaboration on learning communities (IRCLC) composed of researchers who are interested in studying LCs. Given this goal, the purpose of this workshop is to bring together active researchers who study LCs, in all their forms, to better understand the past, present, and future of this central theme in the learning sciences. The workshop will be structured following a LC model, so that norms of trust, collaboration, and multiple zones of participation can be developed, while members share their expertise and contribute to a collective knowledge-building process on LCs.

## **Introduction**

In recent decades, a socio-constructivist approach to learning has increasingly become relevant to education, reflected in the emergence of the learning sciences as a discipline (Bransford, Brown & Cocking, 2000). This shift in the recognition that learning does not take place only in one's mind, but is distributed (Salomon, 1993), has been translated into educational models that are profoundly different than traditional ways that teaching and learning have been practiced (Bielaczyc & Collins, 1999). Among these reconceptualized models, those that have focused on the community have received a great deal of attention, particularly when they were first studied in 1990's (e.g., Brown & Campione, 1994; Scardamalia & Bereiter, 1994). We refer to these models as learning communities (LCs).

The attention that LCs received from learning scientists, as well as their promulgation within various educational settings like schools (e.g., Herrenkohl & Mertl, 2010; Hogan & Corey, 2001; Lehrer, Schauble, & Lucas, 2008; Rogoff, Turkanis, & Bartlett, 2001), universities (Hod & Ben-Zvi, 2013), informal settings (e.g., <http://www.computerclubhouse.org>) and more recently in online settings (e.g., Kafai & Fields, 2013; Resnick, et al., 2009), is reflected in academic journals and conferences. For example, a 2009 EARLI conference had the theme of "Fostering a Community of Learners," out of recognition that "learning is a social process of knowledge construction by collaborating with peers and teachers in communities of learners" (Rijlaarsdam, 2009, p. 5). Even this year's ICLS theme, *Learning and Becoming in Practice*, is at the heart of the LC approach due to its emphasis on enculturation (Brown, Collins, & Duguid, 1989).

While there are many reasons to view the progress that has been made in research and practice on LCs positively, there are still voices of concern. Firstly, to this day only a relatively small number of LCs have been researched and replicated in practical settings. While there may be multifarious aspects above and beyond the learning sciences that inhibit this, one cannot rule out the lack of understanding or under-theorization as a potential factor. Second, although there has been a steady roll-out of articles and research published on LCs, they have hardly been the central theme of articles and conferences. A close look at the same EARLI conference shows there were no efforts to define, revisit or review what is known about LCs. Moreover, for example, in the past two learning sciences international conferences (CSCL 2013, ICLS 2012), the term LC, or one of its relevant equivalents, was a central theme or even loosely addressed in only a relatively small number of papers.

## **Workshop Goals**

Based on the enduring interest of the learning sciences community to explore the LC approach, we make a call with this proposal as a step towards re-invigorating LCs as a central theme of research. Moreover, we are interested in contemporary ways that LCs have been extended. We believe there is great work being done, and the goal of this workshop is to communicate these ideas around the organizing concept of LC theory and practice. As such, our pre-conference workshop will focus on the following questions:

- What is the current status of LC theory and practice?
- What exemplary learning community models exist today that still have yet to be shared but can make a contribution?
- What are current research agendas working on this and what are the key results?
- What interdisciplinary perspectives can contribute to what is known about LCs? How we create a new LC language based on the existing disciplinary languages?
- How is technology used to foster n LC? What are future technological directions?

## Expected Outcomes and Contributions

The workshop is organized around these four guiding questions that the participants will actively negotiate during the day's activities:

- *Who are we?* The purpose of this question is to build the social infrastructure of our international research collaboration on learning communities (IRCLC).
- *What are we interested in?* The purpose of this question is to encourage people to share ideas and elicit the major themes.
- *What are the emergent issues in researching LCs?* The purpose of this question is for the community to identify the issues that need to be developed and studied further.
- *Where do we want to go from here?* The purpose of this question is to reflect upon the day and make commitments (or explore possibilities) for future collaborations

We envision this workshop as the start of an ongoing, International Research Collaboration on Learning Communities (IRCLC) composed of researchers and visionaries who are interested in studying LCs. As an outcome of this research, we suggest publication of a book or special issue in a refereed journal that reports and synthesizes our emergent findings. We will use a collaborative internet platform to pool resources from different disciplines, connect research and practice in various domains, examine current and future challenges, and contribute to a solid research foundation that can significantly advance the field.

## Participation Modes

Participants include practitioners and researchers in all domains who are actively researching, are interested in researching, or want to learn more about the theory and design of LCs. This includes various settings (face-to-face, online, blended, classroom, school, professional, etc.), technologies that support LCs, as well as learning and teaching processes within LCs. The workshop includes two modes of participation: *key contributors* and *participants*.

*Key contributors* are those who actively research LCs in various forms. They will, in addition to being a full participant in the day's activities, lead an approximately 45 minute round-table about the research and design of their LC. Key contributors will also be asked to submit an abstract of their LC (or LC related idea) to enable participants to choose which round-table they will attend.

*Participants* will be selected based on their interest in participating in the workshop and experience with LCs. Participants will be expected to actively engage in the day's activities, contributing to the collective knowledge of the group. Participants with limited or no LC experience, who would like to come to learn, are encouraged to apply.

## Organizers

**Dr. Katerine Bielaczyc** is an Associate Professor and Director of the Jacob Hiatt Center for Urban Education at Clark University. Dr. Bielaczyc's research involves collaborating with students, teachers, and school communities to investigate new approaches to teaching and learning. Her work focuses on developing both technological and social infrastructures to support participants in working together as a knowledge building community to create knowledge regarding personal, pedagogical, and systemic transformation.

**Dr. Dani Ben-Zvi** has a lifetime of experience working with learning communities. He designs and studies technology-enhanced learning communities as means to make complex domains such as statistics and learning sciences more accessible to learners. For the past eight years, he has been the leader of the Educational Technologies Graduate Program in the University of Haifa. Currently, he leads a Research Excellence Center in Israel that examines learning in a networked society in interdisciplinary ways.

**Yotam Hod**, a doctoral student, has over 10 years experience working in and researching LCs. He has spent five years at a celebrated NYC public high school as an assistant principal, leading a community of learners. Yotam has researched a unique LC at the University of Haifa over the past five years, focusing on what social and clinical psychological theories of groups can explain about LCs.

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# Analytics for Learning and Becoming in Practice

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**Abstract:** Learning Analytics sits at the intersection of the learning sciences and computational data capture and analysis. Analytics should be grounded in the existing literature with a view to data ‘geology’ or ‘archeology’ over ‘mining’. This workshop explores how analytics may extend the common notion of activity trace data from *learning processes* to encompass *learning practices*, with a working distinction for discussion as (1) process: a series of related actions engaged in as part of learning activities; and (2) practice: a repertoire of processes organised around particular foci recognised within a social group. The workshop intersperses attendee presentations and demonstrations with relevant theme-based discussions.

## Organizers

**Golnaz Arastoopour** is a graduate student in Learning Sciences in the Epistemic Games research group at the University of Wisconsin-Madison working on engineering epistemic games. Formerly an engineering student and a classroom teacher, she is currently researching how players solve and reflect on complex design problems in engineering games and simulations. Golnaz has organized workshops, tutorials, and has been involved in the development of Epistemic Network Analysis, a discourse and learning network analysis tool.

**Wesley Collier** is a graduate student in learning sciences in the Epistemic Games research group at the University of Wisconsin-Madison working on the Nephrotex project (an engineering epistemic game) and Epistemic Network Analysis. He is interested in how games and simulations can be assessed using discourse analysis.

**Paul A. Kirschner** is professor of Educational Psychology and Programme Director of the Learning and Cognition programme at the Centre for Learning Sciences and Technologies at the Open University of the Netherlands. He is past President of the International Society for the Learning Sciences, member of the Scientific Technical Council of the Foundation for University Computing Facilities (SURF WTR), associate editor of Computers in Human Behavior and chief editor of the Journal of Computer Assisted Learning.

**Simon Knight** is a PhD candidate in Learning Analytics at the UK Open University’s Knowledge Media Institute and researches epistemic commitments in information seeking. He attended the highly competitive Learning Analytics Summer Institute and received a ‘best paper’ nomination for his LAK13 paper. He has reviewed including for the Journal of Learning Analytics and ICLS-2013.

**Simon Buckingham Shum** is a Professor of Learning Informatics and Associate Director (Technology) at the UK Open University’s Knowledge Media Institute, where he leads the Hypermedia Discourse group. He was Programme Co-Chair for the 2012 Learning Analytics conference, a co-founder of the new Society for Learning Analytics Research, and is a regular invited speaker on the topic. He brings a human-centred computing perspective to the challenge of building analytics, collective intelligence and sensemaking tools.

**David Williamson Shaffer** is a Professor of Learning Science at the University of Wisconsin-Madison, is a Principal Investigator at the Wisconsin Center for Education Research. Shaffer is one of the developers of Epistemic Network Analysis (ENA), which uses network models to quantify and visualize the connections that students make between skills, knowledge, identity, values, and epistemology when solving complex problems.

**Alyssa Friend Wise** is an Associate Professor of Education at Simon Fraser University. An integral member of both learning sciences and learning analytics communities, her research focuses on developing digital environments and analytics that work together to promote learning. Dr. Wise serves on the ISLS CSCL Committee, the Executive of the Society for Learning Analytics Research, as an Associate Editor of the Journal of Learning Analytics, and was the Workshop & Tutorial Chair for LAK2013.

## Theoretical Background

Bridging learning sciences and analytic techniques through learning analytics which offer the ability to track an ever increasing number of process and output variables is of great current interest. Indeed, this ‘middle space’ was the theme of the 2013 Learning Analytics and Knowledge conference (LAK13) (Suthers and Verbert, 2013):

In summary, although individual research efforts may differ in their emphasis, we believe that all research in Learning Analytics should address the “middle space” by including both learning and analytic concerns and addressing the match between technique and application. Advances in learning theory and practice are welcome, provided that they are accompanied with an evaluation of how existing or new analytic technologies support such advances. Advances in analytic technologies and methods are welcome, provided that they are accompanied with an evaluation of how understanding of learning and educational practices may be advanced by such methods. (Suthers and Verbert, 2013, p.2)

The core issue is that for learning analytics to have the most effective impact they must attend to the existing research around learning, cognitive, social and epistemological factors (Knight, Buckingham Shum, & Littleton, 2014). Shaffer (2011) noted the problematic nature of the term ‘data mining’ suggesting we should instead refer to ‘data geology’; that is, we must understand the underlying structure of the phenomenon we seek to explore with analytics prior to digging into data.

The “interpretative flexibility” of new technologies – including analytics – is high: when we consider appropriation of technology within particular social settings we should be mindful of not falling into the trap of technological determinism (Hamilton & Feenberg, 2005). As Crook and Lewthwaite (2010) note, our expectations for technology for transformative change should be mitigated by an understanding of those technologies in wider educational systems. Moreover, we should understand that technology’s influence comes about through pedagogic change – not out of technology’s direct effects (Crook & Lewthwaite, 2010). (Knight, Buckingham Shum and Littleton, 2013, p. 6).

This workshop applies these middle space issues to the ICLS conference theme, marking a sharp conceptual distinction between practice and process. The workshop begins with discussion around the status of these two concepts and the ways in which they can be evidenced through the analysis of data traces:

*Process* – a series of related actions engaged in as part of learning activities

*Practice* – a repertoire of processes organised around particular foci recognised within a social group

A focus on practice reflects the growing recognition in educational thinking that students from school age upwards should be given the opportunities to engage in authentic learning challenges, wrestling with problems and engaging in practices increasingly close to the complexity they will confront when they graduate. In higher education the quality of the student experience is under intense scrutiny, as educational systems reflect at national and international levels on their fitness for purpose and value for money. The workforce now needs graduates who are not just academically excellent, but have transferable skills and competencies equipping them to rapidly learn new work practices, and demonstrate the qualities needed to thrive in complexity and uncertainty. This is serving as a driver for action research into new models focused on the holistic design of learning, catalysing academics (Deakin Crick, 2009; Gardner, 1983; Perkins, 1993; Claxton, 2001), national networks and funding programmes (Whole Education, 2014; Hewlett Foundation, 2014). A particular focus of these initiatives is on ‘deeper learning’ that is more authentic in nature—to the extent that the educator may not know the ‘right answer’ but is learning with the students. Indeed, there may be no knowable right answer, such is the open-ended nature of truly “wicked problems” whose very definition sometimes defies consensus (Rittel, 1984). While accuracy of conceptual understanding remains as important as ever, in the absence of a knowable correct solution, it becomes increasingly important to evidence mastery of the appropriate practices through which one may tackle such open-ended problems.

To give a focus, many factors of the developing area of ‘Social Learning Analytics’ (SLA) (Buckingham Shum & Ferguson, 2012) focus on properties of learning which come into being through social activity. In particular SLA relate to: discourse between learners and teachers, social network analysis, content analytics on user generated web 2.0 materials, dispositional analytics regarding the ‘mindsets’ learners bring, and context analytics regarding facets of learner environments. Yet, while tracking and supporting high quality instances of these facets of learning may be important, understanding why such processes are involved in learning or the display of knowledge requires theoretical or/and empirical understanding of the practices in which they are constituted, and which they constitute. It may, for example, be important to explore “interaction

trajectories”, the ways in which processes develop and interact over time, in their social, practice-oriented context (Furberg, Kluge and Ludvigsen, 2013).

Knowledge practices are, thus, fundamental to learning processes – e.g. metacognitive skills, epistemic cognition, self-regulation – and the particular subject domain practices to which we introduce our students, and the degree to which assessments value authenticity. Learning in the context of a practice is an inherently social process where knowledge is co-constructed in some specific social environment, or within some community. Analytically, such learning communities have been described as communities of practice—groups of people that share ways of working, thinking, and acting in the world (Lave & Wenger, 1991). In this view, designed learning environments that are modeled around such communities offer a space for novices to learn processes within the context of the practice. For example, epistemic games are simulations of professional workplaces where participants role-play as interns and learn to think about and solve problems in the ways that professionals within that practice would solve problems (Shaffer, 2007). These simulations provide process and product data from learner interactions that are analysed through the lens of an epistemic frame, the ways in which members of a community make connections between domain-specific skills, knowledge, identity, values and epistemology (Rupp, Gushta, Mislevy, & Shaffer, 2010). The analysis of process data in terms of epistemic frames can reveal something about novice learning processes, such as how novices imitate and internalize the professional ways of thinking that mentors model (Nash & Shaffer, 2011), develop positive associations with the practice (Chesler, Arastoopour, D’Angelo, Bagley, & Shaffer, 2013), and develop the social identity of a practice (Arastoopour & Shaffer, 2013). In other words, designed learning environments based on knowledge practices allow for process data from activities that the community would recognise, and can be analysed in light of community practices.

The notion of practices of learning and becoming is also relevant at the level of analytics use. We need to design and evaluate analytics with not only a view to the processes of how they are used, but also to how they can form part of instructors’ and students’ practices, thus shifting patterns of teaching and learning activity (Wise, Zhao & Hausknecht, 2013). For example, Social Learning Analytics might be productively used to foster data-assisted reflection for the support of the goal-setting, monitoring, and evaluative processes of self-regulated learning. Here again Crook & Lewthwaite’s (2010) concern is key. In order for our expectations for the potential of new tools to be met, we must understand the ways in which they are embedded into educator practice, and the policies around those practices (Piety, 2013).

In sum, the goal of the workshop is to discuss these and other distinctions between process and practice and explore their implications for research and the design of analytic platforms, using participant submissions and organizer examples as useful foci of discussion.

## Objectives

We anticipate that this workshop will provide a space to discuss conceptual issues around analysis of learning and becoming in practice. Short papers and demonstrations will allow for a forum to describe and discuss learning analytics used in the field; the theoretical base/learning science concepts and frameworks surrounding learning analytics; how current work uses data traces to generate evidence of processes, practices or both; and other items/themes for future discussion surrounding learning analytics.

By way of providing illustrative examples, and a potential source of discussion and papers, this workshop will be devoted to hands-on activity. The format will thus include:

1. Short introductory presentations on the emerging field of learning analytics, and practice oriented analytic techniques.
2. Discussion of conceptual issues around process and practice analytics, and their research and design implications. We anticipate this session being resourced by short presentations of accepted papers and demonstrations, followed by a combination of whole-group and break-out-group discussion. The discussion will be shaped by participants but may be focused on the suggested paper submission topics, or particular subject practices (e.g., STEM), etc.
3. The afternoon session is devoted to hands-on demonstrations of approaches to analysis of practice. Demonstrations will be used as a focus for discussion around suitability of analytic techniques for the analysis of learning and becoming in practice alongside discussion of emergent themes from the morning sessions. Participants will be encouraged to consider the broad application of such techniques to their own research agendas. A combination of submitted and invited presentations will be used to resource this session as required. The workshop organisers have experience in and can lead discussion around, demonstrations of Epistemic Network Analysis (Shaffer & Arastoopour) the building of teacher practices around analytics (Wise), and discourse/collective intelligence mapping analytics (Buckingham Shum)

4. Plenary discussion will provide time for considering the theoretical and empirical implications of defining ‘practice’ for research agendas with reference to the learning sciences broadly, and to participants own research programs.

Because of the interactive nature of this workshop, we anticipate that a significant number of participants will continue discussing and exploring topics surrounding learning analytics and practice beyond the workshop. In addition, we expect participants will collaborate on future projects and tool development regarding the relationship between learning analytics, processes, and practices.

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# **Social, Motivational and Affective Dimensions of Learning through Social Interaction**

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**Abstract:** There is strong evidence of the cognitive benefits of collaborative-sense-making through talk and dialogue. However, it is often challenging to *elicit* and *sustain* student participation in such practices. This workshop emerges from growing enquiry across the learning sciences on the social, motivational and affective dimensions of learning through social interaction. Examining and integrating such dimensions in empirical research on learning through social interaction raises fundamental methodological, conceptual and theoretical issues for the field. This workshop aims to bring together scholars from different disciplines to critically examine these issues and to map the terrain for future research.

## **Theoretical Background**

This workshop emerges from growing enquiry in the learning sciences on social, motivational and affective dimensions of learning through social interaction. Research on talk and dialogue has produced strong evidence that certain forms of collaborative sense-making that involves explanation and argumentation, can produce robust learning outcomes (a/o, Resnick, Asterhan & Clarke, in press).

Until recently, research on dialogue has been limited to examining the cognitive processes and outcomes of dialogue. However, it remains challenging to both *elicit* and *sustain* student participation in dialogue (Clarke, in press). Social processes, (e.g. positioning, motivation, affect, and identity), engaged through dialogue may serve as critical pathways to engagement in learning, and therefore, critical pathways to robust learning outcomes. Thus, there is a need to understand the social processes and outcomes of dialogue, to better understand how to support all learners so that they might benefit in terms of robust learning outcomes.

Recently, scholars have become more sensitive to and interested in understanding the social, affective and motivational dimensions of collaborative sense-making, both in classroom as well as in computer-mediated settings (e.g., Baker, Andriessen & Jarvena, 2013; Kreijns, Kirschner & Vermeulen, 2013). Issues of identity, beliefs, interest, and authority can affect students' willingness to engage in dialogue, as well as impact the way in which they choose to engage in it. In computer-mediated dialogue, decreased social presence and sociability are believed to impede on the establishment of rapport, a sense of community and strong interpersonal relationships, which may be necessary for productive learning interactions (Kreijns et al., 2013). In other instances, however decreased social presence may also facilitate learning outcomes, such as in the case of learning through critical argumentation with a disagreeing peer (Asterhan & Babichenko, 2013).

These non-cognitive constructs have been extensively researched in adjacent research fields, such as Sociology (e.g., positioning, identity, norms) and Education (academic motivation), Social Psychology (e.g., small group functioning), and Educational Psychology (e.g., identity, affect). The integration of social, affective and motivational constructs from other disciplines into the study of learning through social interaction then requires the development of new methodologies and, often time, revision or adaptation of 'classical concepts'. This raises fundamental methodological, conceptual and evidentiary questions:

- How can social, motivational and affective dimensions of learning be observed in learning interactions and dialogue, and how can they be distinguished from cognitive processes?
- What are the theoretical and methodological challenges of measuring social-affective- motivational dimensions of learning through social interaction? (Particularly in light of new technologies for learning that provide new forms of data on learning processes.)
- How might we leverage these forms of evidence on learning processes to adapt instruction, in order to better support productive learning through dialogue in practice?

## **Workshop Goals**

This workshop brings together scholars that are active in this emergent area of inquiry in the learning sciences. It aims to attract participants from a range of disciplinary and research traditions, both from within the Learning Sciences, as well as from adjacent research traditions (e.g., classroom dialogue research, CSCL, cooperative learning, argumentation, disciplinary teaching practices, HCI, positioning, motivation, and learning analytics), who use a range of methodological tools (experimental, discursive, ethnographic and computational). This workshop builds on the 2011 AERA research conference on learning through dialogue, and a 2013 EARLI symposium on the barriers and enablers of engaging in learning dialogue. It will constitute the first such workshop that brings together an emerging community of scholars from different disciplines to critically

examine the issues and options for examining social, affective and motivational dimensions of learning in social interaction, and map the terrain for future research.

## Workshop Agenda

### Part I. Short presentations.

The morning session will be dedicated to facilitating detailed knowledge of each other's work, approaches, methodologies and frameworks. All the submitted papers and bios will be available on the workshop website, one week in advance. We will dedicate the morning session to becoming familiar with each other's work through short presentations, Q&A and discussion opportunities. Presenters will be instructed to follow a strict presentation format: 15 minute presentations that will highlight the theoretical framework, the social-affective-motivational construct investigated, methodology, extensive examples of data analyses and the types of research questions addressed. This unified, focused format is expected to not only enhance understanding but also facilitate comparison and integration for the afternoon activities. The review process will seek to identify provocative position papers to help stimulate the discussion on substantive issues.

### Part II. Science Café activities.

The afternoon session will be based on question-oriented organization with lively discussions. 3-4 round tables are organized, each managed by an assigned Moderator. Each Moderator/table will be focused on one substantive area to probe groups on in small group discussion. The 3-4 discussion topics will be decided and formulated in advance by the organizers in consult with the Program Committee and based on the submitted position papers. The groups will go through a round-robin of discussions with each moderator, rotating tables every 20-30 minutes. Therefore, in the 1 ½ round-robin, each group will have spent 20-30 minutes in small group discussions with all of the Moderators.

The groups will be assembled so as to ensure maximum disciplinary heterogeneity, based on the short bios submitted by each workshop participant. Moderators will begin their small group discussions with a brief overview of their topics, and probe groups as they discuss, raising the challenging questions. The Moderator will write the main ideas for each group on a sheet. When groups move through the round-robin, the Moderator will lead subsequent groups in discussions that build on issues raised in previous group discussions. This is expected to push the limits of these issues over the course of round-robin.

The round-robin will be followed by a short coffee break, during which moderators will sort out the main themes from each table. Moderators will present these themes in a plenary session (30 minutes). The final hour will be dedicated to a plenary open discussion with all participants, led by one of the Committee members. This discussion will focus on four main questions:

- What do we know?
- What are the implications?
- Where should we go next?
- What are productive and fruitful venues for future interdisciplinary collaboration?

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# Exposing and Assessing Learners' Epistemic Thinking

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**Abstract:** The conceptualization of students' personal epistemologies has been criticized for being inconsistently defined, overly simplistic, and inappropriately decontextualized. Broadly, epistemic cognition encompasses explicit thoughts about the nature of knowledge as well as reasoning processes related to knowledge claims and justifications. Learning scientists are invested in understanding epistemic cognition in a variety of authentic settings, but it is challenging to analyze data in meaningful epistemic categories. Participants in this workshop will briefly discuss varied conceptualizations of epistemic cognition and will focus on how to apply these conceptualizations to empirical research. We will explore empirical methods that extend beyond traditional interview and questionnaire methods to better expose authentic, ongoing epistemic thinking. Presentations and discussions will explore means of revealing epistemic thinking in classrooms and other settings and methods of analyzing data from learners' interactions and discourse. A primary goal of the workshop is to foster collaborative, interdisciplinary future work.

## Theoretical Framework

Epistemic cognition broadly refers to an array of understanding, practices, and motivations related to topics such as what counts as knowledge and how knowledge claims are justified. Included in this array are the practices and processes for achieving knowledge. As such, epistemic cognition encompasses both explicit beliefs as well as situated reasoning practices. Recent work by learning scientists, as well as others, has challenged overly simplistic conceptualizations of epistemic cognition (c.f., Chinn, Buckland, & Samaratungavan, 2011). These challenges have emphasized the situated nature of epistemic cognition and have severely criticized some of the most common methods of measuring epistemic cognition, such as questionnaires. At the same time, recent work has stressed and begun to reveal evidence for the role of epistemic cognition in reasoning skills important for learning, education, and civic responsibility (e.g., Bagley & Shaffer, 2009; Schommer-Aikins & Easter, 2006).

A primary challenge for researchers investigating epistemic cognition is that its definitions and the specification of its key components vary widely. On one hand, this means that although emerging trends may be similar across studies, variations in how epistemic cognition is conceptualized create an obstacle for integrative reviews of the relevant literatures (Maggioni & Parkinson, 2008). Differences in terminology and operational definitions result both in a rich array of ideas for analyzing epistemic cognition and in difficulties making sense of how the diverse approaches tie together. A central goal of this workshop is not only to share ideas about how to conceptualize epistemic cognition but to share and discuss how these conceptualizations play out in the analysis of data. We frame the workshop in terms of epistemic cognition, emphasizing students' explicit thoughts and beliefs as well as their reasoning processes and motivations relevant to the nature of knowledge and knowing.

Most research on students' personal epistemologies has relied on quantitative data from questionnaires and surveys. This methodological approach is most likely responsible for the widespread characterization of individuals' epistemologies in terms of a naive/sophisticated dichotomy across prescribed, domain-general dimensions such as certainty, structure, and source of knowledge (Greene, Azevedo, & Torney-Purta, 2008; Maggioni & Parkinson, 2008; Mason, Ariasi, & Boldrin, 2011). One approach to correcting simplistic conceptualizations has extended research beyond domain-general individual beliefs about the nature of knowledge to include survey measures that consider domain-specific individual epistemologies (see Stahl & Bromme, 2007; Maggioni, VanSledright, & Alexander, 2009), epistemic practices (see Hennessey, Murphy, & Kulikowich, 2013) and motivations (see DeBacker & Crowson, 2008). However, more qualitative approaches, including student interviews and think alouds, have revealed that epistemic cognition is more complex, nuanced, and context-dependent than questionnaire-based research has indicated (see Alexander, Winters, Loughlin, & Grossnickle, 2012; Ferguson, Bråten, & Strømsø, 2012; Gottlieb, 2007; Gottlieb & Wineburg, 2012). Research situated in inquiry environments has shown further that students' specific epistemic practices and their ideas about these specific epistemic practices are much more sophisticated than what has been revealed by questionnaire-based research and even interview research (Herrenkohl & Cornelius, 2013; Pluta, Chinn, & Duncan, 2011). It is evident that epistemic cognition is not only situated within a particular domain, or discipline. Instead, recent studies suggest it is situated within task and context as well. For example, in a review

of studies of teachers' epistemologies, Maggioni and Parkinson (2008) found contextual constraints with regard to curricular and institutional factors, including student contribution to classroom discourse.

## Rationale

Research aimed at learners' knowledge acquisition and reasoning must investigate cognitive, metacognitive, *and* epistemic processes. Extensive research in the scientific reasoning literature has examined cognitive mechanisms related to skills such as hypothesis generation and experimental design in science and source evaluation in history (for review see Zimmerman, 2007; Wineburg, 1991). Metacognitive processes such as hypothesis revision, explanation, and argumentation also have been studied extensively with regard to student learning, particularly in science and math domains (Kuhn, 2005). Coherent, interdisciplinary study of epistemic cognition, however, is only beginning to emerge. As mentioned above, traditional approaches for studying student epistemology have relied on interviews and questionnaires, which have been severely criticized as inadequate methods. More recent emphasis on learners' epistemic cognition and related practices calls for investigating situated facets of epistemic cognition and its progression in authentic settings, such as ongoing inquiry environments. We aim, with this workshop, to bring consideration of means of exposing and analyzing learners' epistemic thinking in such environments to the forefront of this area of inquiry. We expect this framing to be particularly relevant for considering the relation among facets of epistemic thought *and* between epistemic processes and meaningful, effective instruction.

The study of learners' epistemic cognition is challenging and the problems of measuring epistemic cognition in its many facets continue to vex the field. Specific challenges create a need for better ways of modeling practical modes of epistemic cognition (Greene, Torney-Purta, & Azevedo, 2010). For instance, we need better ways of analyzing practices (such as practices exhibited in oral discourse) in terms of epistemic categories (Chinn, Buckland, & Samarapungavan, 2011). It is also the case that developmental trajectories of epistemic cognition are unclear in the current literature base. This calls for better ways of modeling students' epistemic cognition progressions within and outside of instructional contexts. To address the challenges raised here, we see as a vital first step the convening of researchers engaged in work that involves novel approaches to exposing epistemic thinking beyond traditional questionnaire and interview methods.

Beyond novel approaches to *exposing* epistemic cognition, challenges must be addressed through relevant assessment and analysis. The *Exposing and Assessing Learners' Epistemic Thinking* workshop allows for sharing recent and ongoing attempts at uncovering learners' epistemic and related thinking processes and for discussing next steps in data analysis and future study design. Exploring means of assessing students' thinking is timely as practitioners and researchers consider how to align assessment with the newly released Common Core and Next Generation Science Standards (NGSS). NGSS, in particular, emphasize the integration of student knowledge and practices requiring not only summative, but formative assessment aimed at revealing *how* students are thinking (National Research Council, 2013). As such, the National Research Council (2013) has called directly for new modes of assessing student thinking and assessing the development of students' understanding of knowledge and associated practices. We expect a discussion of means for assessing learners' epistemic thinking to be highly relevant to this call.

## Goals

In order to address the challenges outlined here, the first goal of the workshop is to promote dialogue surrounding design research of epistemic cognition's nature and development. This goal counters the current trend for segmented, disciplinary study of student epistemologies by targeting an interdisciplinary focus on design research. This goal also emphasizes the situated nature of epistemic cognition, especially in authentic settings. We expect such focus is best for advancing our understanding and modeling of epistemic cognition beyond prior discrepant conceptualizations. The second goal of the workshop is to explore workshop participants' conceptualizations of the *measurement* of epistemic cognition. Within this goal, strong emphasis will be placed on the practical dimensions of epistemic cognition in authentic settings such as the classroom. Importantly, emphasis will not necessarily be limited to dimensions of epistemic cognition that students are able to access and reveal metacognitively. Third, we aim for the workshop to foster discussion of means of analyzing, interpreting, and expanding on existing data. The fourth and final goal of the workshop is to provide opportunities to develop collaborative work across disciplinary lines. Epistemic cognition has been studied through various theoretical lenses – each of which provides a different perspective on the construct. Overall, we aim to converge these perspectives with a specific focus on research design and data analysis in this area. Discussion will aim at fostering collaborative products such as a special topics issue, for example on proposals for exposing epistemic thinking and analyzing data, review papers, or future studies.

## **Connections to the Conference Theme**

The ICLS 2014 theme of “Learning and Becoming in Practice” highlights the need to develop an understanding of real learning and thinking practices. This workshop seeks to move the study of epistemic cognition from largely decontextualized questionnaires and interviews to settings of rich, authentic inquiry practices. Following long standing philosophical and theoretical consideration of epistemic cognition, it is important to begin exploring possibilities regarding the practical applications of this research -- that is, to determine viable approaches for assessing epistemic cognition, its progression within the individual, its impact on learning, and the role of authentic instructional interventions in promoting its development. By encouraging interdisciplinary participation, we echo the ICLS theme’s recognition that the community of scholars represents a myriad of stances, all with valuable potential to contribute to the advancement of this line of research.

## **Workshop Agenda: Expected Contributions and Outcomes**

Workshop participants will be invited to submit abstracts in order to present their work. Abstracts submitted for workshop acceptance will be required to include recent or ongoing considerations of epistemic cognition or related reasoning processes. Relevant related reasoning processes may include those such as evidence or source evaluation, argumentation skills, or the psychology of understanding. Emphasis will be placed on research that involves design-based methods of revealing epistemic thinking in the practice of inquiry. In the event more abstracts are received than can be accommodated, preference will be given to presentations of collected data. We expect this will best facilitate discussions of practical methods of data analysis as well as methods for eliciting students’ epistemic cognition. Accepted abstracts and examples of measures, tasks, transcripts, and coding schemes will be posted by facilitators on a wiki page prior to the workshop. The proposed full day workshop will include a fire hose presentation session, whole group discussion, and discussions in smaller “breakout” groups that focus on specific topic strands.

Fire hose presentations will provide the opportunity for participants to present their perspectives with regard to methodology for exposing epistemic thinking. Each presenter will take three minutes to describe his or her current conceptualization of epistemic cognition framed around recent or ongoing methods of assessment and analysis. Fire hose presentations will promote the cross-disciplinary work espoused by our workshop. Following fire hose presentations, workshop facilitators will moderate a whole group discussion structured according to our primary goals. Having whole group discussion immediately after fire hose presentations will give participants an opportunity to respond to peers’ work, as well as to engage in further discourse about the challenges that may arise as epistemic cognition is considered. The discussions will focus on (1) how to conceptualize epistemic cognition, (2) how to expose and capture epistemic cognition in interactive environments, (3) how to analyze data in terms of epistemic categories, and (4) important but neglected areas of research. Ideas generated during discussion will be captured on large sticky notes for later compilation and distribution to small groups. A main goal of this task is to develop a broad range of ideas that merit further exploration and to organize these ideas around challenges specifically related to the workshop and broader ICLS conference theme. Whole group discussion will generate questions and issues to be discussed further in specific topic strand discussions.

Small group discussions will follow whole group discussion. Although facilitators may have ideas for specific topic strands after reviewing the research proposals submitted by workshop applicants, topics will largely emerge in whole group discussion. As an example, a topic strand might address coding schemes for analyzing revealed student thinking. We aim to recruit interdisciplinary researchers and will also encourage topic strands that are representative of these varied perspectives. We aim to have 4-6 distinct topic strands. Small groups will be charged with deciding on an appropriate resulting product (e.g., special topics issue, or review paper) and devising a plan for completing the product. Following the breakout discussions, each group will be given an opportunity to present an overview of their discussions and conclusions. We will close with questions and comments following small group presentations and remarks.

## **Workshop Organizers**

**Maggie Renken** is Assistant Professor in the College of Education at Georgia State University. Her research explores how science knowledge is acquired, considering the role and development of mechanisms like epistemic cognition. Her study of hands-on experimentation and computer-simulated experiences in students’ physics knowledge is published in *Learning and Instruction*. Work developing a measure of psychology-specific epistemological beliefs is in press in *Teaching of Psychology*.

**Clark Chinn** is Professor in the Graduate School of Education at Rutgers University. His research focuses on epistemic cognition, argumentation, and promoting growth in reasoning through model-based inquiry. Drawing on philosophical work, he and his colleagues recently argued for a substantive reconceptualization of epistemic

cognition in a 2011 paper in *Educational Psychologist*. He is currently working on developing epistemic coding schemes to understand students' interactions in inquiry classrooms.

**Penelope Vargas** is Assistant Professor in the Eugene T. Moore School of Education at Clemson University. Her research focuses on the relationships between epistemic beliefs and motivations, and justification processes in different domains. Her work on epistemic cognition and making sense of evidence in history will appear in the *Journal of Social Studies Research* in 2014. She is currently working on investigating the connections between epistemic cognition and researcher identity in engineering and science students.

**William Sandoval** is Associate Professor in the Graduate School of Education & Information Studies at UCLA. He is interested in the development of epistemic cognition especially in relation to people's understanding and engagement with science. He has written on the topic in Science Education and Journal of the Learning Sciences, and the 2012 ICLS proceedings, and is currently co-editing the first ever Handbook on Epistemic Cognition to be published by Routledge.

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## MOOCShop 2014

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**Abstract:** Moocshop 2014 ([Moocshop.org](http://Moocshop.org)) is the second iteration of the Workshop on Massive Open Online Courses, an interdisciplinary forum for researchers to address the pedagogical and technological opportunities in designing and evaluating MOOCs. Using a participatory problem-solving framework, the goal of Moocshop 2014 is to collaboratively generate priorities for platform development, instructional strategies, and research in MOOCs, with a clear emphasis on learning. The facilitators and presenters will lead a set of activities and discussions around integrating insights from the learning sciences into the design of MOOCs, as well as how MOOCs provide opportunities for the learning sciences as a site for research.

# **Mediated Action and Mediated Discourse Analysis: Studying Learning and Becoming at the Nexus of Practice**

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**Abstract:** The purpose of the workshop is to explore the closely related frameworks of *mediated action* (MA) (Wertsch, 1998) and *mediated discourse analysis* (MDA) (Scollon & Scollon, 2004). In the spirit of a study group, participants will 1) engage in a dialogue around what these frameworks can bring to the learning sciences, 2) get hands-on experience analysing empirical material from these two perspectives, 3) discuss their own research practices within these frames. One anticipated outcome of the workshop is the development of a research agenda and an international network in the learning sciences with a particular focus on MA/MDA.

## **Workshop Description and Goals**

The goal of this workshop is to explore how learning science research might be informed by the closely related frameworks of *mediated action* (Wertsch, 1991, 1998) and *mediated discourse analysis* (Scollon & Scollon, 2004). In line with the conference theme, both perspectives focus on processes of becoming through engagement in practice, and how these processes of becoming are realized through communication and participation in value-laden settings of action.

MA theory explores how mind is realized in and through action, and how forms and processes of realization are mediated by semiotic and material “cultural tools.” This approach takes *action*, as opposed to either individuals or sociocultural environments, as the fundamental unit of analysis for studying learning and psychological development in general. MDA builds directly on the MA framework, adding specific emphases on, first, the role of discourse as a form of action through which mind, identity, positionality, and social collectives are realized; and, second, an ethnographic understanding of the “sites of engagement” in which action takes place, including the range of semiotic and material tools that intersect in action.

Both frameworks seek analytically to adopt a focus not exclusively on individual actors, nor on social groups or institutions, nor on mediational means, but rather on the “nexus of practice” at which these intersect and are brought concretely into engagement (Scollon, 2005, p. 20). This focus keeps alive the complexity of meanings and practices that bind communities together and make up individuals’ identities over time. Both approaches aim at deepening our understanding of how sociocultural processes shape and mold people’s lives and identities, and both are interested in better understanding how discourses, practices and mediations sometimes constitute opportunities for actions, but sometimes also contribute to limiting action and imagination. Each of these interests has also been a key focus of recent work in the learning sciences.

Despite these commonalities, and despite the international and interdisciplinary reach of both perspectives, researchers in the two fields have seldom had formal opportunities to meet together to exchange ideas and mutually develop the perspectives. One of the major goals of the workshop, then, is to bring together scholars influenced by these two traditions for dialogue and exchange on a central question of this year’s conference: How does engagement in practice bring individuals to become certain kinds of persons over time. More specifically, the workshop would like to take up questions such as: How does learning contribute to new individual and social trajectories? How does it help people to imagine or make connections to different possible futures (de Saint-Georges, 2012; O’Connor & Allen, 2010)?

A second goal of the workshop is to give attendees hands-on experience using MA/MDA as analytical and methodological perspectives. In small groups, participants will be invited to unpack and discuss empirical material thematizing different aspects of “learning and becoming” from these perspectives. Finally, attendees will also be asked to discuss their own research agendas and practices as they are developing them within the frameworks under discussion or within related approaches.

By the end of the workshop, we hope to foster the creation of an international network in the learning sciences around MA/MDA. To make this network concrete, an academic blog will be launched on Hypotheses.org, a platform aimed at enhancing visibility of research in the humanities and social sciences. Attendees will be free to disseminate their work through this platform, which can also become a space for organizing future encounters and events beyond ICLS2014.

## **Why an International Network in the Learning Sciences around MA/MDA?**

It might be timely to reflect about the rationale behind developing an international network in the learning sciences around MA/MDA now. Wertsch’s sociocultural theory has developed over the last thirty years. Scollon and Scollon’s mediated discourse analysis is a bit more recent dating back only to the late 90s (Norris & Jones,

2005; Scollon & de Saint-Georges, 2011). Over the last decades, both frameworks have attracted the attention of a growing body of researchers who have found in these approaches ways of responding to thorny epistemological and methodological questions. For example, MA has attracted researchers by offering concrete tools to approach in a more principled way the relationship between processes across multiple timescales, focusing as it does not just on the moment-by-moment unfolding of actions but also on the multiple social, historical, and cultural processes that traverse these actions through the cultural tools used to perform them. To the interested researcher, MA has designed a way to overcome the traditional dichotomy between the mind and the social. It has also helped in theorizing the role of cultural experiences and material and symbolic resources in developmental processes (Zittoun, 2006).

As for MDA, researchers attracted to this framework often highlight two important reasons for turning to this approach. The first reason is the interest MDA has in beginning investigations not so much from theoretical or methodological questions but from real-life ‘problem’ or ‘social issue’ and then considering which actions, practices and discourses might be constitutive of these issues (Scollon, 2005). It makes this framework particularly adapted to design research with an impact, as well as to reflect about the position of researchers as producers of discourses and actions which might affect the very nexus they study. A second dimension that is often highlighted as a reason for adopting MDA is its commitment to interdisciplinarity. As Hult (2010) puts it, MDA is a form of ‘meta-methodology’ which aggregates the findings and tools from diverse disciplinary orientations (e.g. interactional sociolinguistics, linguistic anthropology, critical discourse analysis, social semiotics, mediated action, cultural psychology, etc.) to put them in the service of addressing the problems of interest. In that, MDA thus also offer a framework for overcoming traditional disciplinary boundaries.

Interested in the affordances these frameworks offer, an increasing number of researchers are engaging in using ‘mediated action’ in their investigation or in doing ‘mediated discourse analysis’ or ‘nexus analysis’ in various fields and geographical areas. In the field of ‘mediated discourse analysis’, for example, the *Jyväskylä Discourse Research hub* (*University of Jyväskylä*) and the *Peripheral Multilingualism* (*Academy of Finland*) have recently launched a joint ‘reading group’ on nexus analysis (the methodological arm of MDA) which is bringing together scholars from eight different countries across the US and Europe to discuss their work in virtual space in relation to this framework (<http://www.discoursehub.fi/events/jyvaskyla-discourse-research-hub/>). Internationally, there has been research done in the field of multilingualism and language policy (Hult , 2014; Compton 2014), political discourse (Dunne, 2003; Shroyer, 2004), disability studies (Al Zidjali, 2006), risk communication and management (Jones, 2013), digital literacies (Jones & Hafner, 2012), workplace practices (Serwe & de Saint-Georges, 2014; de Saint-Georges, forthcoming a, b), identity (Lane, 2010, 2011) to name but a few areas. There is also today a clear strand of research which, following the seminal work of Scollon on the learning of intercultural practices by a one-year old (Scollon, 2001), has taken on MDA in the field of learning and education with, for example, studies on the nexus of literacies, play and technologies in early childhood (Wohlwend, 2009a, b, c, 2011, 2013; Wohlwend & Handsfield, 2012), learning in vocational education (de Saint-Georges, forthcoming a, b), writing practices in secondary English Education (Rish, 2011), learning in various informal contexts (Norris, 2011; Jocuns 2007, 2009), international supervision (Soukup & Kordon, 2012), etc.

The field of mediated action, with its interest in how mediational means become appropriated and mastered and serve developmental processes, has long resonated with the learning sciences. Here the focus has been not only on learning (Herrenkohl & Mertl, 2011; Herrenkohl & Wertsch, 1999; Polman, 2006), but also on domains such as transitions (Zittoun 2006), moral functioning (Tappan 2006), identity (Wertsch & Penuel, 1995a, 1995b), and historical identity and representation (Wertsch, 2002; Wertsch & O'Connor, 1994). Throughout this body of work, attention has been paid to processes of learning and becoming, and to the contingency of the appropriation of cultural tools in the production of trajectories (O'Connor & Allen, 2010; Penuel & O'Connor, 2010).

As we can see from this short account, MA and MDA are lively, dynamic and growing fields of inquiry. Despite this growth however, there are no journals or conferences dedicated specifically to these approaches, nor real forums to exchange and debate about them. The benefits of such exchanges between researchers are, however, clear. They would allow to debate about epistemological, methodological and theoretical perspectives in deeper ways. For this, the creation of an international network seemed suited to the task, and ICLS seems a perfect venue to lay the ground for such a network.

## Practical Organization

### Audience

We conceive of the workshop as kind of study group where participants read, listen, analyse, comment, learn together and build an agenda for research collectively. We welcome scholars at any level (masters and doctoral students, post-docs and established researchers) including those who are beginning to explore how an MA/MDA framework can enrich their own understanding of ‘learning and becoming in practice’ as well as those who

already have a longer history of research in the learning sciences with one of these frameworks as their starting point (or related approaches such as, e.g. cultural-historical activity theory, discourse analysis, actor-network theory).

## Pre-conference Preparation

To ensure lively discussions, a few preparation steps are required from prospective attendees.

- 1) Prior to the event, prospective participants are invited to send to Ingrid de Saint-Georges ([Ingrid.desaintgeorges@uni.lu](mailto:Ingrid.desaintgeorges@uni.lu)) and Kevin O'Connor ([kevin.oconnor@Boulder.EDU](mailto:kevin.oconnor@Boulder.EDU)), a half-page summary of their research interests as they relate to the theme of the workshop, including specification of research focus and level of familiarity with the related frameworks of MA and MDA. While preference will be given to participants who are already working at the interface between MA/MDA (or related approaches such as, e.g., cultural-historical activity theory, discourse analysis, actor-network theory) and the learning sciences, other participants who can show how their research would benefit from exploring these two frameworks or who are just curious about it are most welcome too. The summary will also enable the organizers to group participants according to their interests for some of the workshop activities.
- 2) In addition to this half-page summary, prospective participants will also be sent a short reading package as well as a general bibliography to prepare for work together. It will be expected that all attendees have prepared themselves for participation in the workshop through reading these documents.
- 3) If participants so wish, there will be also the possibility to take on a more active role in the workshop, for example, by bringing some data for exploration by the group, or by bringing up some issues and topics for discussion. In this case, the participants should contact the organizers prior to the workshop ([ingrid.desaintgeorges@uni.lu](mailto:ingrid.desaintgeorges@uni.lu) and [Kevin.OConnor@Colorado.EDU](mailto:Kevin.OConnor@Colorado.EDU)) so that we can communicate more information about the specific format this intervention could take.

## Facilitators and Workshop Organizers

The workshop organizers as well as the facilitators who will lead the workshop have all long-term expertise in the field of Mediated Action and Mediated Discourse Analysis and come from various geographical areas.

**Andrew Jocuns** is a Research Lecturer at Thammasat University in Bangkok, Thailand. His research has focused on learning in a variety of contexts including: Balinese Gamelan in the US, engineering students, STEM professionals, homebrewers, and sociolinguistics in Indonesian Borneo. Presently he is conducting research on STEM students in Southeast Asia. His research has used mediated discourse analysis and related theories (e.g. distributed cognition) to identify patterns of informal learning such as the use of participation structures by students. Jocuns' articles have appeared in *Semiotica*, *Mind, Culture, Activity* or the *Encyclopedia of Applied Linguistics*, among others.

**Sigrid Norris** is Associate-Professor of Communication Studies at Auckland University of Technology in New Zealand. Her current research is in the field of multimodality in everyday life, identity, and learning. She has been active in the field of Mediated Discourse Analysis for the last ten years, developing it further theoretically and methodologically, to for example, study the learning of how to smell perfume or the learning of tacit classroom participation in an art school. She is the author of *Multimodality in practice: Investigating theory-in-practice-through-Methodology* (2012), *Identity in (Inter)action: Introducing Multimodal (Inter)action Analysis* (2011), *Discourse in Action: Introducing Mediated Discourse Analysis* (2005, with R. Jones), *Analyzing Multimodal Interaction: A methodological Framework* (2004).

**Kevin O'Connor** is currently Assistant Professor in Educational Psychology and Learning Sciences at the University of Colorado Boulder. His research focuses on communication and learning in a variety of contexts, including engineering education and community organizing. His publications have long drawn on the Mediated Action framework (e.g., Wertsch & O'Connor, 1994) and have used this and closely related approaches to frame his ethnographic and discourse analytic research on learning. He is co-editor of a volume of the *Yearbook of the National Society for the Study of Education* on "Learning research as a human science," and his work has also been published in *Mind, Culture, & Activity*; *Linguistics & Education*; *Anthropology & Education Quarterly*, and the *Encyclopedia of Cognitive Science*, among others.

**Ingrid de Saint-Georges** is an Associate-Professor in the field of Education and Learning at the University of Luxembourg. She studies communication, professional development, and learning in different contexts, including work and vocational education. She is an early contributor to the development of Mediated Discourse Analysis (see e.g. Scollon & de saint-Georges, 2013), a framework she uses to examine learning in situations of increased mobility and diversity. She is the co-author and editor of several books, including (in English):

*Multilingualism and Multimodality: Current Challenges for Educational Studies* (2013, with J-J Weber), *Multilingualism and Mobility in Europe: Policies and practices* (forthcoming 2014, with J.J Weber & K. Horner), *Multilingualism: Opportunities and Challenges* (forthcoming 2014, with N. Morys, G. Gretsch & C. Kirsch).

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# **Interaction Analysis of Student Teams Enacting the Practices of Collaborative Dynamic Geometry**

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**Abstract:** Analyze evidence of mathematical learning in a CSCL approach. Make collaborative learning, group cognition and formation of team practices visible in the discourse. Conduct fine-grained interaction analysis of logs across a sequence of chat sessions using the Virtual Math Teams collaboration environment incorporating multi-user dynamic-geometry software. Analyze changes in the student team's ability to engage in collaboration, software usage, geometry construction, problem solving, mathematical reasoning, design of geometric dependency and creative exploration – underlying practices of collaborative dynamic geometry. Join researchers and experienced interaction analysts to discuss data from this long-term design-based-research CSCL effort. Details and materials: <http://gerrystahl.net/vmt/icls2014>. Contact: Gerry@GerryStahl.net.

# **Writing Competitive Proposals for Programs in NSF's Division of Research on Learning in Formal and Informal Settings**

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**Abstract:** The National Science Foundation supports innovative research, development, and evaluation of learning and teaching across STEM settings. This workshop focuses on understanding the priorities of DRL's programs and provides guidance in writing competitive, high quality proposals. The workshop is structured to include opportunities for collaborative work, discussion, and questions. The content of the workshop includes: 1) STEM educational research in DRL; 2) priorities and changes in DRL's major programs, 3) NSF's proposal review process; and (4) characteristics of competitive and poorly-rated proposals. Both novice and experienced researchers are encouraged join in the discussions and to bring proposal concepts for discussion.

## **Theoretical Framework**

The primary goal of the workshop is to examine the proposal-writing process and NSF's review criteria for researchers interested in submitting proposals to DRL. While the basic structure of NSF and DRL is unchanged from the previous review cycle, most DRL programs and solicitations for proposals have been revised, as are the priorities and emphases of Division administrators. The revisions reflect the changing priorities and the evolving nature of foundational knowledge and practices in STEM education across settings and age groups. Along with new approaches to K-12 science education (NRC, 2012) and undergraduate biology education (AAAS, 2011), there are new standards for what students should know and be able to do (NGSS, 2013). The desired changes in student learning outcomes, instructional practices, and approaches to evaluating progress will require both large-scale studies of educational practices and smaller exploratory studies of new innovations that may have the potential to transform current practices. For long-term success, these efforts must be solidly grounded in sound theoretical frameworks and based on strong evidence of effectiveness.

The National Science Foundation wants to identify and support researchers who will take up these new challenges. In the broader context of Federal support for education research and evaluation, DRL's challenge is to be a catalyst for change in advancing theories, methods, measurements, resource development, and applications in STEM education. The Division seeks to meet this challenge by supporting both early, promising innovations and larger-scale adaptations of educational innovations shown to be effective.

NSF is the premier Federal agency supporting research and development at the frontiers of discovery in the STEM fields, so DRL takes as a central principle that new and emerging areas of STEM must figure prominently in efforts to improve STEM education at all levels and in all settings.

## **Rationale**

The primary rationale is to increase capacity among the communities of STEM education researchers to write competitive and high quality proposals. In this regard, it is important to understand the larger context of NSF goals for scientific research. The NSF context includes: emphasis on potentially transformative research; NSF culture of evolving programs to meet dynamic opportunities; evaluation and accountability expectations; research and development with respect to the *Common Guidelines*; and knowledge and evidence base for change.

## **Goals**

Workshop participants will better understand: DRL's major research programs and priorities; the NSF review process; essential elements of strong proposals; common weaknesses in proposals; and the mechanics of proposal preparation. Presentations will set the context for the priorities of NSF, EHR, and DRL. There will be a brief discussion of NSF's current structure and organization and funding levels. The bulk of the time will be spent on the NSF proposal review process, what makes a proposal competitive, and how DRL thinks about "rigor" in education research. Participants will have multiple opportunities for interaction. This will be accomplished two ways: First, participants will critique and discuss prearranged scenarios that demonstrate proposal strengths or weaknesses highlighted in the presentation, and second, participants will have opportunities to describe and get feedback on their own research ideas.

## **Structure**

The workshop is comprised of multiple segments to vary the format and provide opportunities for interaction. Part 1 (45 min) begins with an introduction to DRL's funding programs: Education Core Research (ECR); Advancing Informal Science Learning (AISL; formerly ISE); Discovery Research K-12 (DRK-12), Promoting Research and Innovation in Methodologies for Evaluation or PRIME, Innovative Technology Experiences for Students and Teachers (ITEST), and Faculty Early Career Development (CAREER).

Facilitators will describe the programs' objectives, topical strands, types of awards, and provide examples of projects supported by each program. The session will then continue with an overview of the NSF review timeline and merit criteria – intellectual merit and broader impact – and DRL-specific expectations and procedures. A brief overview of related programs within the Education and Human Resources Directorate and across the NSF directorates will also be provided. The purpose of this session is for participants to understand the programs' foci and the review process.

In Part 2 (90 min), participants will split into smaller groups. During this time, the participants will first read a scenario – a short passage designed to stimulate discussion about strengths and weaknesses of proposals. The scenarios are likely to include: 1) brief passages that address important proposal elements such as national significance, role of STEM content, connections to theory-building or testing, and rigor and evidence in study design; and 2) brief summaries of potential research projects or study ideas, which Program Directors occasionally receive from potential applicants.

The scenarios will be prepared by Program Directors as exemplars. Passages from real proposals are used, and have been approved through the NSF's Office of the General Counsel's process. This is also an opportunity for participants to discuss their own questions in a smaller and more congenial environment.

Part 3 (45 min) will explore the qualities of successful (and unsuccessful) proposals. This presentation will include discussion of common strengths of highly-rated proposals and typical weaknesses of poorly-rated proposals. It will also include clear examples that will relate directly to the two NSF merit review criteria and to the DRL programs. Practical guidelines for presenting a compelling case for a proposed project will be presented during this portion of the workshop, with suggestions about how to convince reviewers that a proposal is worthy of support. Useful NSF resources, such as the *Grant Proposal Guide* (NSF, 2013) and related guidelines will be described. Participants' questions are encouraged.

The small groups will rejoin for Part 4 (45 minutes). Participants will shift from discussion of pre-arranged scenarios to discussion of their own questions or individual proposal ideas. This format allows participants to bring up questions or points of discussion about the programs or about the review process in a smaller and more congenial environment. To support open dialogue, participants are invited to share a brief summary of a potential research topic or study. As mentioned above, Program Directors commonly receive brief summaries of this type from researchers and are asked to provide feedback on both the selection of the appropriate program and on the potential strengths and weaknesses of the idea. After having read and discussed the scenarios, participants may be more comfortable with their small group to mention their research ideas.

# **Tightening Research-Practice Connections: Taking ISLS Findings to Public Debate**

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**Abstract:** This session will: sensitize participants to the importance of sharing research findings with non-researchers (e.g. teachers, school leaders, policy makers, parents); inform participants about existing strategies for engaging in public debate; and support participants in forming collaborative outreach projects. During the workshop, collaboration teams will identify specific research insights to be shared with non-researchers; start shaping key messages; and select approaches for engaging in public debate (e.g. New York Times editorial, NSTA workshop). After the workshop, teams will develop and implement the planned outreach approaches. Thereafter, a paper and/or journal special issue is envisioned, documenting the processes.

## **Background**

A robust body of knowledge now exists to describe how policymakers and educators access, value and use research; various modes through which knowledge is generated and shared; and what aspects of evidence-based practice and research utilization in other fields can be applied to education. However, both the scholarly insights and effective practices have yet to become widely spread. Even though researchers are becoming increasingly required to disseminate research findings among practitioners, few graduate programs devote serious attention to preparing researchers for the task, and many researchers find it daunting. The proposed workshop addresses this element of “learning and becoming” in researcher practice by (a) sharing insights and examples from existing projects that stimulate fruitful research-practice connections; and (b) facilitating the design of strategies through which ISLS can contribute to public debate.

## **Theoretical underpinnings**

Educational research has long been criticized for its weak link with practice. Explicit attempts to close the research-practice gap have been underway for over four decades. These efforts have included design team approaches and researcher-teacher models aimed at making practice the object of investigation. Shrader, Williams, Whitcomb, Finn and Gomez (1998), for example, described a research for practice approach, in the Learning Sciences, that involved working collaboratively with teachers to design, enact, and refine science materials. Lampert (1992) and Ball (Lampert & Loewenberg-Ball, 1998) taught in classrooms and made their practice an object of study. Yet, much of the work that would be useful happens in silos, is known to a few, and is rarely leveraged by policy makers, school administrators and teachers to improve educational practice. We have learned much about what aspects of evidence-based practice and research utilization in other fields can be applied to education, yet, how to share current knowledge, generate and share new knowledge, and walk the knowledge-sharing communicative path between research and practice remains a significant challenge in the Learning Sciences. Internationally, enormous efforts have been launched to improve the practical relevance and actual use of research knowledge, especially in the fields of education and health care.

Informed by the work of Rogers (1969), and review of over 2600 research studies, Havelock (1971) published a landmark report on the dissemination and use of scientific outputs. Havelock identified seven general factors that could account for how scientific outputs are taken up and used: linkage, structure, openness, capacity, reward, proximity and synergy. He identified several modes in which those factors can be seen: social interaction; research, development and diffusion (RDD); and problem solving. More recently, attention has also been given not only to the use of scientific knowledge for educational practice (e.g. Hargreaves, 1999; Levin, 2004), but also to how it is produced (Vanderlinde & van Braak, 2010). Specifically, there is growing attention for how researchers and practitioners can collaboratively bear the responsibility for both producing and using relevant knowledge in education.

Burkhardt and Schoenfeld (2003) identify seven models to describe the relationship between research and practice, five of which feature strong divisions of labor, relate more to evidence-based practice and align well with the RDD model described by Havelock, and two of which show more characteristics of Havelock’s problem solving model (both featuring design). Each of these models denotes different assumptions and expectations regarding the roles of practitioners and researchers in the generation and application of theoretical understanding.

The proposed workshop draws on evidence-based practice from RDD and design research to initiate what we hope will provide the foundation for the design of principles that inform ISLS members about approaches to sharing research findings with non-researchers (teachers, school leaders, policy makers, parents, the general public), and raise awareness about existing strategies for engaging in public debate about the use of evidence-based research for practice. In addition, we hope to contribute to the ways that Schools of Education support graduate students in building scholarship that keeps consideration of how to share findings with practitioners as a central component of the research and dissemination process.

## Workshop Structure

### Before the Workshop

A Call for Participation will be issued in early February through the ISLS mailing list. Participants will submit their experiences and insights concerning the workshop theme in the form of short papers (1000-2000 words). This may be based on theoretical, methodological or practical work that has been presented elsewhere, or in the current conference, and will provide seed ideas to be synthesized into specific outreach messages. Through a structured review process by the workshop organizers, all papers clearly relevant to the workshop theme will be invited for inclusion. All participants will be given access to all papers, and encouraged to read especially those that have been clustered into the same –emergent– theme as their own. Authors will be asked to send a brief presentation (1 powerpoint slide) to the organizers the week before the workshop. Though working groups during the workshop may change slightly, the screening and clustering process will help us make the most efficient use of our precious time together.

### During the Workshop

As previously indicated this workshop aims to: (a) sensitize participants to the importance of sharing research findings with various stakeholder groups (teachers, school leaders, policy makers, parents, the general public); (b) inform participants about existing strategies for engaging in public debate; and (c) support participants in forming collaboration teams that will get started identifying and shaping a core message (during the workshop) as well as developing and implementing an outreach vehicle (e.g. New York Times editorial, NSTA workshop) to inform public debate (after the workshop).

To meet these aims, the workshop is divided into four main stages. The *first* stage is intended to sensitize and inform participants by sharing insights and strategies from existing examples of both successful outreach strategies, and incidents where an ISLS voice (or similar) seemed severely lacking. With the goal of informing and inspiring, the examples will exhibit variation in message content, target groups and dissemination media. Strategies for sharing (emerging) insights will be discussed in terms of: content (focus), form (products and activities), medium (face-to-face, online, etc.) and time (sustained, bursts, frequency, etc.). At least one project will represent each of the aforementioned orientations (RDD; design research). During the *second* stage of the workshop, participants will be encouraged to articulate the kinds of messages they might like to disseminate, and to discuss these with like-minded individuals. This will be facilitated by single powerpoint slides that participants will have created ahead of time. Working groups will discuss message content and potential target groups.

During the *third* stage of the workshop, working groups will consider and outline a specific outreach vehicle they intend to develop and implement. They will document their work using shared GoogleDocs, live, during the session. During the *final* stage of the workshop, participants will report back to the group, discuss potential overlaps and give constructive feedback to each other.

The workshop will last for 3.5 hours with a 30 min break at the standard break time. The workshop agenda is provided below.

- 2.00-2.45: Welcome, brief introductions, goals, background, examples
- 2.45-3.30: Brief presentations, group forming
- 3.00-3.30: Break, form working groups for designing after break
- 3.30-4.00: Identify focus, establish mission, set goals
- 4.00-5.00: Refine focus, outline outreach strategy, document work
- 5.00-5.30: Report back, conclusions, action items

### After the Workshop

Following the workshop, teams will be supported in the process of realizing their outreach strategies, sharing them with one another, and more broadly. Specifically, a paper or journal special issue is envisioned which documents messages worth sharing outside the ISLS community, and journeys taken to do so.

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## **Constructing Assessment Items That Blend Core Ideas and Science Practices**

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Joseph Krajcik, Michigan State University)  
Christopher Harris, SRI International

**Abstract:** How do you measure knowledge in use? In this workshop, participants will apply principles of Evidence-Centered Design to construct assessments that meet the ambitious goal of integrating disciplinary core ideas with practices, much like in the Next Generation Science Standards. In small groups, participants will unpack assessable components of science standards and construct learning goals that integrate aspects of core ideas and science practices. Participants will learn design principles for specifying evidence that students need to meet the learning goals and define task features to elicit the desired evidence. Using these design principles, participants will craft items and rubrics.

# NAPLeS: Networked Learning in the Learning Sciences

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**Abstract:** The workshop about networked learning in the Learning Sciences is based on the ISLS initiative to establish a network for PhD and Master's programs in the Learning Sciences. The main objective of this network is to support the academic exchange for professors and students in Learning Sciences programs worldwide. An important question that has been raised in several meetings of members of the network is how learning material for students in the Learning Sciences can be developed, used in Learning Sciences classes worldwide and evaluated for sustainable learning. This workshop will bring together Learning Scientists to discuss this question from various perspectives including those concerned with pedagogy, technology networked learning and evaluation. Finally, the participants will come up with a feasible plan for the development, implementation and evaluation of learning materials that can be used across Learning Sciences programs worldwide.

## The Network of Academic Programs in the Learning Sciences (NAPLeS)

The International Society of the Learning Sciences (ISLS) is formed by a community of academics, practitioners and students from different disciplines (e.g. cognitive science, educational sciences, psychology, sociology) who are concerned with research and practice in the scope of teaching and learning (ISLS, 2009). Over the years, the Learning Sciences community has become increasingly international with active members from North America, Europe, and Asia, but also South America, Australia, and even Africa (Kienle & Wessner, 2006). The community is characterized by non-institutionalized collaborations and exchanges among scholars located in different countries and representing various disciplines (Hoadley, 2005). Because of the ad-hoc nature of these collaborations, it has been difficult for students and young researchers who wish to affiliate with the Learning Sciences to access the enormous amount of knowledge the community has generated over the years. NAPLeS seeks to address this challenge, giving students and young researchers greater access to community knowledge and helping them to become active members in a scientific community (Eberle, Stegmann, & Fischer, 2014). Graduate students in the Learning Sciences are often educated only within their university's Learning Sciences programs, which naturally reflect the research foci and viewpoints of the local faculty. Having access to the broader Learning Sciences community and the variety of disciplines and perspectives concerned with teaching and learning could enrich their graduate training, and offer sustained access to postdoctoral scholars and early career professors.. The NAPLeS initiative is designed to provide such access.

The educational aims of the ISLS are to facilitate Learning Sciences students and young researchers in their effort to acquire knowledge in the multiple fields of the Learning Sciences, to conduct and publish Learning Sciences research, and eventually become active members of the global Learning Sciences community (ISLS, 2009). To realize these aims and to foster high quality Learning Sciences programs internationally through mechanisms that support teaching and learning, the ISLS has established the Network of Academic Programs in the Learning Sciences (NAPLeS), an institutional network of PhD and Master's programs in the Learning Sciences.

Before NAPLeS was founded in the summer of 2012, an extensive search for international academic Learning Sciences programs was conducted. In the spring of 2012, a survey was sent to 37 universities worldwide that offered Learning Sciences and related academic programs, in order to investigate which academic Learning Sciences programs would be willing to contribute and what they would expect from participating in NAPLeS.

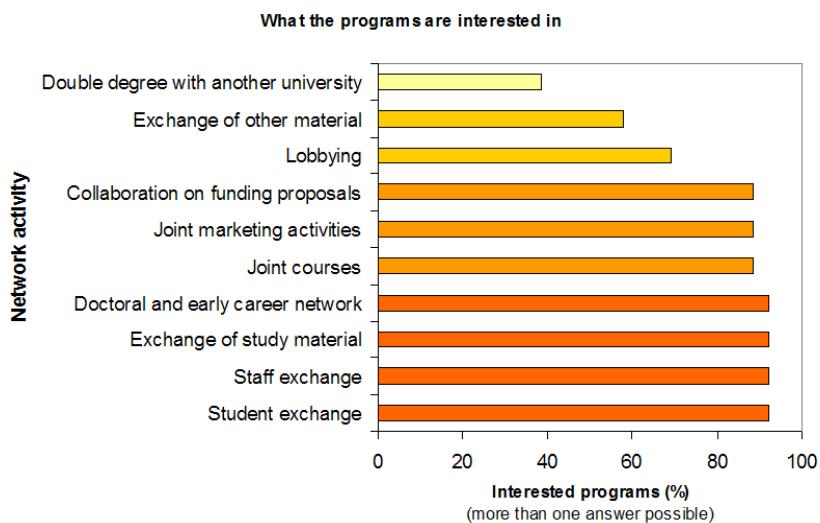


Figure 1. Types of activities in which the Learning Sciences programs were interested

The survey was well-accepted, with a response rate of about 70% responding that they were very interested in joining a network, with particular interests in the exchange of learning materials, staff, and students with other Learning Sciences programs (see figure 1). However, the survey also revealed that most of the programs were not at all or only to a very slightly willing or able to financially contribute to the network (see figure 2).

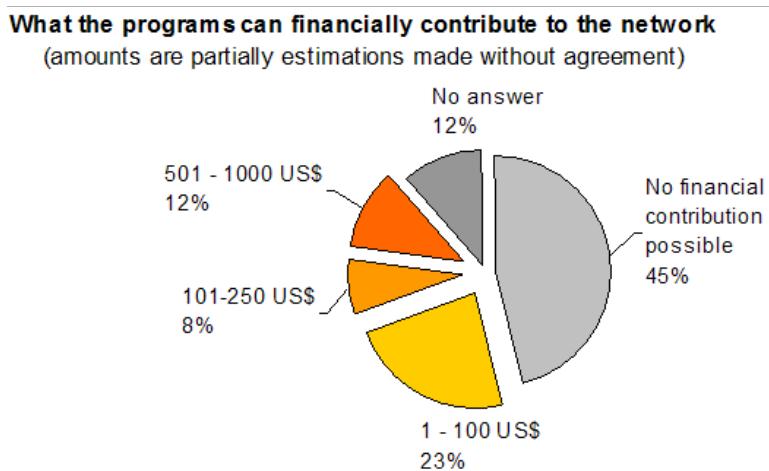


Figure 2. Budget the Learning Sciences programs could contribute to the network

Against the backdrop of the outcomes of this survey, a NAPLeS taskforce was formed and started to plan several activities to be implemented in the network, with an emphasis on low cost of participation and early return on investment. Amongst others, the activities included:

- Collecting examples of syllabi used in existing Learning Sciences programs.
- Creating learning resources prepared by renowned scholars on specific topics in the Learning Sciences.
- Offering scholarships for students to visit other Learning Sciences programs.
- Facilitating the organization of international supervision of doctoral projects.

To ensure the quality of participating programs, it was agreed that to join NAPLeS, a graduate program must offer (or be preparing) a PhD and/ or Master's degree in the Learning Sciences, with at least three ISLS members associated to the program (two of whom should be faculty). Furthermore, NAPLeS member programs (and their associated faculty and students) are expected to actively participate in the network in following ways:

- Naming a program representative (e.g., a PhD student) to serve as a liaison for NAPLeS
- Submitting program information, to be presented on the NAPLeS website
- Providing visiting scholar opportunities for other NAPLeS students

- Submitting exemplary syllabi for exchange with other NAPLeS members
- Collaboratively developing and exchanging learning materials (e.g. on the NAPLeS webinar series).

After the initial planning phase, the NAPLeS network was officially founded at the 2012 ICLS meeting, beginning with programs from 12 member institutions. Since then, many new programs have joined, and currently NAPLeS has more than 30 programs affiliated to 24 different member universities (see Table 1).

Table 1: Location of NAPLeS member universities and type of programs (March, 2014)

University	Location	Learning Sciences program
Carnegie Mellon University	Pittsburgh, PA, USA	Master's, PhD
Indiana University	Bloomington, IN, USA	Master's, PhD
Nanyang Technological University	Singapore	Master's, PhD
New York University	New York, NY, USA	Master's, PhD
Northwestern University	Evanston, IL, USA	Master's, PhD
Open University of the Netherlands	Heerlen, The Netherlands	Master's, PhD
Rutgers University	New Brunswick, NJ, USA	PhD
Saarland University	Saarbrücken, Germany	Master's
Stanford University	Stanford, CA, USA	Master's, PhD
University at Buffalo - State University of New York	Buffalo, NY, USA	Master's, PhD
University of California, Berkeley	Berkeley, CA, USA	PhD
University of California, Los Angeles	Los Angeles, CA, USA	PhD
University of Haifa	Haifa, Israel	Master's, PhD
University of Illinois at Chicago	Chicago, IL, USA	PhD
University of Munich (LMU)	Munich, Germany	Master's, PhD
University of Nottingham	Nottingham, UK	Master's, PhD
University of Oulu	Oulu, Finland	Master's, PhD
University of Pennsylvania	Philadelphia, PA, USA	Master's
University of Pittsburgh	Pittsburgh, PA, USA	PhD
University of Sydney	Sydney, Australia	Master's, PhD
University of Toronto	Toronto, Ontario, Canada	Master's, PhD
University of Washington	Seattle, WA, USA	Master's, PhD
University of Wisconsin-Madison	Madison, WI, USA	PhD
Utah State University	Logan, UT, USA	Master's, PhD

Since the official initiation of the NAPLeS network, many Learning Sciences programs, as well as Learning Scientists not affiliated with a member program, have contributed to the collection and exchange of learning resources. Currently, the NAPLeS website gives access to more than 15 syllabi from different Learning Sciences Master's and PhD programs in various topic areas representing the multitude of contents in international Learning Sciences. In October of 2013, NAPLeS launched an online seminar series – the so called “webinar series” – with more than 50 of the most influential and renowned researchers in the Learning Sciences. The webinars are categorized into four main topics, namely (1) how people learn, (2) supporting learning, (3) methodologies for the Learning Sciences, and (4) Computer-Supported Collaborative Learning. These four topics and the broad spectrum of researchers serve to reflect the multiple research areas within the Learning Sciences. Each webinar session has been recorded and shortly afterwards the corresponding video recording made available as a resource on the NAPLeS webpage – not only to serve as a resource for learning and teaching in Learning Sciences programs, but also for the general public. Up to today, 25 webinars have been conducted and are now available on the NAPLeS website (see the ISLS home page).

A look at the access statistics of the NAPLeS webpage reveals that all digital learning resources on the NAPLeS webpage have been quite well received. Since the webinar series started, the NAPLeS webpage has up to 21,000 hits per month and more than 1,400 unique visitors from over 30 different countries worldwide. But it is not only the recordings of the webinars that are popular. The syllabi collection is also highly frequented, with a total number of up to 545 downloads per month.

Nevertheless, it is still an open question how these video recordings and other learning resources can be optimized for access and uptake within the community, and how they can be successfully integrated into curricula and informal learning processes. Most importantly, as we are a community concerned with the nature of learning and instruction, it seems evident that the pedagogical approaches being researched within the Learning Sciences field might be more systematically applied to facilitate learning within our own community.

The challenge, then, is to identify principles derived from Learning Sciences research that can serve to guide the design of these digital learning resources and give clear recommendations for their use in different curricular and informal environments.

## **Objectives of the NAPLeS Workshop at ICLS 2014**

The NAPLeS workshop at ICLS 2014 should bring together professors, post-docs, and PhD students to discuss about the Learning Sciences as a domain of learning in an international context. Participants will discuss potential formats of learning resources to ensure sustainable learning for PhD and Master's students in the Learning Sciences. Specific topics to be discussed are: learning and technology, networked learning, community building, and collaborative learning at a distance. Four expertise teams will be formed to discuss this issue to arrive at a concept of how to realize digital learning resources in the Learning Sciences in the future, and how these digital resources can be used in Learning Sciences degree programs and beyond. Additionally, a timeline will be created covering concrete steps for the implementation of the concept into the NAPLeS network and NAPLeS activities. The concrete objectives of the workshop are as follows:

1. Creating a concept for the development of digital learning resources in the Learning Sciences from a pedagogical, technological, and community building perspective.
2. Developing recommendations for lecturers in the Learning Sciences, regarding how to implement these digital learning resources in their own Learning Sciences courses.
3. Planning future activities within the ISLS community to create, share, and evaluate learning resources.

The outcomes of the workshop will be used as foundation for the creation and preparation of learning resources for PhD and Master's students in the Learning Sciences. Furthermore, the outcomes will provide guidelines for lecturers in the Learning Sciences how these resources may be integrated into their own teaching. As an extended activity and outcome of this workshop, the workshop organizers will create high quality video recordings of short introductory talks or interviews of different learning scientists throughout the ICLS conference. The digital resources and instructions, which will be created during this ICLS workshop, will then be made available for lecturers and students in the Learning Sciences (ISLS and/ or NAPLeS members).

## **NAPLeS Workshop Expertise Teams**

The creation and use of digital learning resources for PhD and Master's students in the Learning Sciences will mainly be discussed in four distinct expertise teams and from their specific points of view.

### **Pedagogical Issues**

When designing and publishing digital learning resources, pedagogical questions cannot be ignored. This team will clarify the pedagogical issues related to the creation of digital learning resources for students and lecturers in the Learning Sciences, discussing the functionality needed for new online resources, the goals for their use in teaching and learning, and the pedagogical aspects that must be considered. This team will also consider how pedagogical approaches from Learning Sciences research can be systematically applied.

### **Technological Issues**

When talking about digital learning resources, technological aspects of learning have to be considered as well. Research results about digital and online learning and also the increasing number of available online learning environments both have to be taken into account when planning for the new digital learning resources. This expertise team will work on the use of technological developments for the digital learning resources, taking into account the constraints given by the limited funding of the NAPLeS network.

### **Networked Learning**

The NAPLeS network aims to create a worldwide community of Learning Sciences students as a platform for networked learning and as a starting point for their integration into the ISLS community. This expertise team will discuss how networked learning and community building aspects can be facilitated within the NAPLeS network and how the facilitation could be enhanced by including different digital learning resources.

### **Evaluation**

Creating more digital learning resources is only one side of the coin. Carefully assessing and evaluating them is equally important to ensure a high quality and usability of the resources. In order to make sure that the digital learning resources fulfill their pedagogical objectives, match the high standards of the community and reflect the communities' needs, an ongoing process of evaluation is required. This expertise team will work on a plan for the evaluation of the digital learning resources in NAPLeS.

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## **Acknowledgements**

Beyond the authors of this paper, an international group of professors, post-docs, and PhD students has been working on the NAPLeS mechanisms and activities. We would especially like to thank: Kim Gomez, Eleni Kyza, Jim Pellegrino, Peter Reimann, and Baohui Zhang.

## **Design Charrettes**

A design charrette is an intensive, collaborative experience that brings together stakeholders to develop a shared understanding of the diverse needs a design must meet, and to brainstorm possible ways to address those needs through engaging directly in design. It is a fast-moving experience that involves “thinking with your hands” and pushes the boundaries of how we expect to interact with our colleagues around research and development. Participant-designers are tasked with developing models, experiences, objects or materials that address particular goals, constraints, and scenarios of use. Whole group and sub-groups engage in design-based activities that can include hands-on modeling, role-play, story boarding, etc. Ideas under development are presented and discussed throughout the session to promote discussion and innovation.

### **Designing for Student Agency and Authority around Issues of Climate Change**

Victoria Hand, CU-Boulder

Leilah Lyons, University of Illinois at Chicago

Chrystalla Mouza, University of Delaware

Elizabeth Walsh, San José State University)

**Description:** The effects of climate change may be most profoundly felt starting ten years from now. Today's young people, then, will be the primary inheritors of these effects. In response, organizations are investing resources in opportunities for youth to take action in political and social spheres around climate and pollution (e.g., Green Ninja; UN Children, Youth and Climate Change; Energy Action Coalition). This design charrette will contribute to this effort by drawing on powerful media and educational resources to develop materials for civic engagement of middle school students. The design process will involve high school students and learning scientists in activities that inspire creative and systems-level thinking around climate change. High school students will be positioned as key contributors to this process.

### **The Learning Theater: Designing a Flexible Reconfigurable Space for Ambitious Learning and Teaching on Campus**

Gary Natriello, Columbia University

Hui Soo Chae, Columbia University

**Description:** A renewed interest in experimentation with new forms and formats for learning and teaching on college and university campuses is creating pressure to re-think the spaces available for students and faculty to come together for learning. Projects as diverse as the ASU Decision Theater (<http://dt.asu.edu>) the MIT TEAL Project (<http://web.mit.edu/edtech/casestudies/teal.html>), and the Learning Space Toolkit (<http://learningspacetoolkit.org/>) illustrate the growing spirit of experimentation that is driving the creation or renovation of spaces intended for learning. All too often learning scientists are brought into such projects late in the design and development process or not at all. This design charrette will engage learning scientists in the design of a space to support ambitious learning and teaching.

# Research-Practice Partnerships Workshop

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**Abstract:** This NSF-funded workshop is designed to support a community of STEM researchers, district and school leaders, formal and informal educators, and community coalitions engaged in building and sustaining *research-practice partnerships* to improve STEM education.

## Focus of the Workshop

This NSF funded workshop aims to build a community of STEM researchers, district and school leaders, formal and informal educators, and community coalitions engaged in building and sustaining *research-practice partnerships* to improve STEM education. Research-practice partnerships are long-term collaborations between practitioners and researchers that are organized to investigate problems of practice and solutions for improving the outcomes of educational systems (Coburn, Penuel & Geil, 2012). In STEM education, Math and Science Partnership Program projects funded by the National Science Foundation are examples of design partnerships that bring together subject matter experts in higher education, mathematics and science education researchers, and school districts. There are also funded partnerships in which a network of formal and informal education organizations are linked together and with researchers to organize more robust and equitable learning ecologies for youth (Bang, Medin, Washinawatok, & Chapman, 2010; Falk et al., 2013).

Our aim for building a network of such partners is to *increase the capacity of the field for continuous improvement in STEM education*. Our specific objectives for this workshop are to:

- Build knowledge and skill of a network of doctoral and early career researchers (see RPP Workshop for Early Career and Doctoral students) who can form and maintain long-term partnerships with districts, informal education organizations, and community coalitions focused on STEM improvement.
- Create a network of mature research-practice partnerships focused on next generation mathematics and science learning and equity that produces resources and knowledge to benefit new partnerships.
- Develop knowledge about effective partnership strategies and about how best to support a network of scholars focused on partnership work and a network of research-practice partnerships.
- 

Our basic premise for this work is that STEM improvement at scale requires new opportunities and infrastructures for fostering ongoing exchange between research and practice. This premise is grounded in conclusions from a recent consensus report that concluded that regular interactions between researchers and practitioners were the most effective strategy for promoting the use of evidence to guide policy (National Research Council, 2012).

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## Acknowledgments

Funding for this workshop has been provided by the National Science Foundation (DRL Award #1408510).

# **Research-Practice Partnership Workshop for Doctoral and Early Career Researchers**

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**Abstract:** This NSF-funded workshop is designed to support early career and doctoral students in STEM research to work with district and school leaders, formal and informal educators, and community coalitions in order to build and sustain *research-practice partnerships* to improve STEM education.

## **Workshop Leaders**

Bronwyn Bevan, Exploratorium, Director of the *Institute for Research and Learning*

Andrew Shouse, University of Washington, Director of the Institute for Science & Math Education

## **Mentors**

Kris Gutiérrez, Professor, University of Colorado Boulder

Tricia Harding, *Synergies* Project Community Organizer

Ben Kirshner, Associate Professor, University of Colorado Boulder

Matt Krehbiel, Kansas State Department of Education

## **Focus of the Workshop**

This workshop is designed to support a community of STEM researchers, district and school leaders, formal and informal educators, and community coalitions engaged in building and sustaining *research-practice partnerships* to improve STEM education. Research-practice partnerships are long-term collaborations between practitioners and researchers that are organized to investigate problems of practice and solutions for improving the outcomes of educational systems (Coburn, Penuel & Geil, 2012). In STEM education, Mathematics-Science Partnerships funded by the National Science Foundation are examples of design partnerships that bring together subject matter experts in higher education, mathematics and science education researchers, and school districts. There are also funded partnerships in which a network of formal and informal education organizations are linked together and with researchers to organize more robust and equitable learning ecologies for youth (Bang, Medin, Washinawatok, & Chapman, 2010; Falk et al., 2013).

Our aim for building a network of such partners is to *increase the capacity of the field for continuous improvement in STEM education*. Our specific objectives for this workshop are to: (1) Build knowledge and skill of a network of doctoral and early career researchers who can form and maintain long-term partnerships with districts, informal education organizations, and community coalitions focused on STEM improvement; (2) Develop knowledge about effective partnership strategies and about how best to support a network of scholars focused on partnership work and a network of research-practice partnerships.

## **References**

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## **Acknowledgments**

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# **Participant Summaries for Special Workshops**



**Research-Practice  
Partnership Workshop  
for  
Doctoral and Early Career Researchers**



# **Exploring Longitudinal Outcomes and Trajectories of English Language Learners (ELOTE)**

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## **Partnership**

WestEd will partner with a large urban school district (SWSD) in the Southwest. The Quality Teaching for English Learners initiative at WestEd will engage with the Bilingual/ESL Department of SWSD with the close cooperation of the Office of Research and Program Evaluation.

## **Purpose**

The English language learner (ELL) graduation rate in SWSD is 38%, the lowest percentage of all subgroups. Fifty-four percent of immigrant students were dropouts, the highest percentage of any subgroup. The partners will improve graduation outcomes of secondary ELLs by jointly: 1) investigating ELL academic outcomes and trajectories, 2) determining indicators that identify students who will require additional supports and predict outcomes, 3) identifying promising programs and interventions.

## **Setting**

SWSD has over 82,000 students, with 36,000 at the secondary level. ELLs account for 28% of the student population. As part of the articulated district policy for ELLs, immigrants who arrive after the fifth grade attend Recent Arrivals Secondary School (RASS) for one year. After engaging in language and content development at RASS, students enroll in self-contained Language Centers hosted at seven middle school and four high school sites. As immigrant ELLs achieve English proficiency, they transition into mainstream classes. Students who are over the age of 17 upon entry into the system attend a separate program which incorporates career readiness.

## **Sample**

The focus of this project is on secondary ELLs and in particular recent immigrants. Each year, approximately 200 new immigrant students enter at the ninth grade level and approximately 200 enter in grades six through eighth. In the district, approximately 2,000 students fall under the federal definition of "immigrant," which refers to students who have arrived to the United States within the past three years.

## **Primary Research Method**

Secondary analysis of existing administrative data will allow the identification of outcomes and trajectories for secondary immigrant ELLs. Of particular interest are indicators and predictors, such as "on-track" performance in a given grade, of summative outcomes such as graduation. These outcomes and trajectories for secondary immigrant ELLs will be contrasted with other relevant subgroups, including non-ELLs and U. S.-born ELLs. Because previous research has indicated that schools are an important variable, the results of this large-scale analysis will be complemented by pilot case studies of school sites that are identified as having higher than average ELL performance.

## **Measures and Outcomes**

Key outcomes include English proficiency, academic achievement, and summative outcomes such as graduation. English proficiency will be measured by scores on the state proficiency exam. Academic achievement includes scores on state tests in subject areas as well as course enrollment and grades.

## **Data Analytic Strategy**

Methods for the secondary analysis include multi-level logistic regression to identify predictors of summative outcomes such as graduation, latent growth modeling to identify academic trajectories, and survival analysis to determine timing of student exits from the school district. A pilot study of select school sites will incorporate student and teacher focus group, classroom visits, administrator interviews, and analysis of school documents and artifacts.

# **Designing Culturally Relevant Technology Based Learning Environments Across Formal and Informal Spaces**

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## **Description of Research Agenda**

Broadly my research focuses on finding out how formal and informal environmental education curricula/programs lend itself to actual decision-making in everyday life. I am also interested in the impact of curriculum delivery on everyday life decisions – the question that I am interested in is: how can we tie research, schools and communities together so as to create an optimal learning environment for students? Within the above-mentioned context of learning for environmental decision-making my research agenda focuses on the areas that are discussed below.

## **Supporting Learning to Impact Everyday Life Decisions**

As a lead researcher for the Himalayan project I have been working on how to help communities in climate underprivileged areas of the Himalayas adapt to the changing environment. Along with a strong network of learning scientists, educators, teachers, curriculum designers and community partners, I have been able to outline several different pedagogical approaches that can be used to help communities innovate and design solutions to build resilience and adapt to the changing environment.

## **Designing Technology Based Curriculum for Learning Across Formal and Informal Learning Environments**

I am interested in researching and designing learning environments that help individuals understand complex interactions that exist between the society, culture and place. In order to design technology based learning environments that support learning across formal and informal spaces I have used methods such as participatory video. Participatory video (PV) involves the use of video between and within groups for self-evaluation and enhanced understanding, at both individual and community levels. The method has allowed me to connect in classroom discussion to the outside community. Through community interviews, on-site documentation of physical realities, and a flexible participatory decision-making process, participatory video has proven to be a powerful tool for bringing together students with their communities in order to help them evaluate the relevance of the school curriculum to their everyday lives.

## **Assessment of Learning Environment Designs**

I am in the process of designing the first ever impact assessment for different environmental education curricula used in schools across South Asia (India, Bhutan and Nepal). The aim is to assess the impact of formal environmental education curriculum on actual everyday life decision – making processes across several communities in South Asia. As a part of this assessment I am looking at the impact of classroom teaching on everyday life decision-making practices among the students. The work is being grounded in concepts such as empowerment evaluation.

## **Technology Supported Cross-Cultural Collaborative Learning Environments**

I believe that no one individual or community has the knowledge or capacity to address the current environmental crisis faced by the world. Since the last 10 years I have successfully used appropriate technologies to connect several communities of students across the world so as to find out whether learners situated in culturally diverse environments can share knowledge and understand each other's perspective to create a dialogue for negotiation. In this regard I have worked on two different research projects that looked at the social and ethical dimensions of student perceptions of climate change. In one of the projects we documented how values and ethics of students from climate underprivileged countries are differed from those of the United States. Thus providing a platform for discussion on how to achieve equity when it comes to environmental issues faced by the communities around the world.

Moving forward I would like to continue my work in designing learning environments that include equal participation from teachers, school administrators, informal learning organizations and community members.

# **Blended Learning, Analytics, and Mathematics Achievement in Washington D.C. Public Schools**

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## **Research-Practice Partnership**

Over the last two years, the Washington D.C. Public School System (DCPS) has experimented with various technology investments to pursue blended learning throughout the district including: (1) purchases of two digital, games-based, mathematics platforms ST Math (<http://www.mindresearch.net/programs/>) and First in Math (<http://www.firstinmath.com/>), (2) hiring of district staff such as Manager of Blended Programs and Instructional Coordinators to facilitate implementation across the district, and (3) pilot elementary and middle schools (and soon high schools) that are moving to a fully-blended model of instruction.

## **Research Questions and Theoretical Framework**

Our design-based implementation research (DBIR) has focused on two research questions: (1): How could blended learning improve student achievement in mathematics? And (2) How has DCPS implemented blended learning? What are the experiences of different stakeholders across the system from district-level administrators, instructional coordinators, principals, and teachers? And what lessons can we learn about effective implementation?

To explore these questions we are utilizing regression analysis to understand (1) the patterns of adoption of different platforms and its relationship with school-level factors (e.g. socioeconomic status, percent minority etc.), and (2) correlations between student activity in video game platforms with 6 waves of DCPS standardizes assessments in mathematics. In conjunction with the quantitative analysis, we are conducting case studies that examine the rich history, implementation decisions, and understanding of blended learning that occurred in these cases. Our focus is to examine how different stakeholders understand blended learning, their role in this district change, and how they came to these understandings (information trails, influences, social networks etc.). Our goals are then to relate these implementation processes to the ultimate pedagogical decisions that we observe in the classroom. The hope in these studies is to inform the district about issues of capacity and implementation, in order to improve the district's efforts over time.

One goal of this project is to integrate perspectives from the Information Sciences, Learning Sciences, and Education Policy Implementation research to understand this complex, sociotechnical system. We are drawing from information science traditions such as *social informatics* that are concerned with understanding the impacts of computerization, or technological change in social settings (Kling, 2007). Unpacking the historical and social trajectory of blended learning in DCPS is one goal of this project, with the aim of describing the rich interconnections between policy, implementation, social, cultural, and pedagogical influences as stakeholders throughout the district react to this technologically-mediated change. This fine-tuned observation of interconnected factors – or the fit of a technological change with existing school institutions – is also a thread of learning sciences and education policy research that is concerned with sustained, systemic change (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000; Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004; Zhao & Frank, 2003). A unique component of this project is the integration of perspectives from Information Sciences, Learning Sciences, and Education Policy Implementation. We hope that practical observations about how policy and implementation occurs in DCPS and its fit with blended learning models can also be framed within the broader theoretical propositions of social informatics, learning sciences, and education research.

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## Exploring Learning in Out-of-School Settings

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Building on many years of experience as an educational practitioner (developing and evaluating museum exhibits and leading workshops for children and adults), Nan Renner sought a deeper theoretical understanding of how people learn. Her doctoral dissertation (UCSD Cognitive Science), entitled *Free to Explore a Museum: Embodied Inquiry and Multimodal Expression of Meaning*, documents and describes children's multimodal engagements in a natural history museum. She addresses fundamental questions: How do children use museum exhibits? How do they make sense of experience when confronted with a wide array of resources, including specimens, environments, models, digital and mechanical interactives, images, text and sound? How does design constrain and afford different forms of engagement and meaning-making?

To answer these questions, Renner conducted ethnography of a cognitive ecosystem. Microanalysis of multimodal interaction and detailed coding of first-person and third-person video focused on six multilingual fourth-grade children using museum exhibits. The behavioral coding scheme highlighted how and when the children look, touch, talk, and gesture with exhibits. Quantitative analyses focused on behavioral frequencies and sequences. Qualitative analyses described the forms and cognitive functions of the children's multimodal engagements. In the cognitive ecosystem of a museum, the diversity, abundance, and distribution of modes of interaction permit inferences about the role of the environment, consequences of design and the potential for learning.

Children's self-directed explorations of the museum clustered around themes: objects, action, and representation. The children's activity embodied inquiry. They asked, explicitly and implicitly, *What is it? What can I do? What does it mean?* Children used multiple sensorimotor and expressive modalities for different functions, and they distributed and integrated cognitive labor across modalities and individuals. When children manipulated objects in the museum—opportunities for interaction that they actively sought—they achieved feats of cognitive complexity. They tested cause-and-effect relations in the physical world, created layers of narrative interpretation, and filled conceptual gaps in exhibits with their own expressions of meaning.

The *Bilingual Exhibits Research Initiative* (NSF 1010666, with Steve Yalowitz, Cecilia Garibay, and Carlos Plaza) had two foci: current practices in the creation of bilingual exhibits and the visitor experience in bilingual museum exhibits. The research targeted two different populations: informal STEM education professionals and multi-generational bilingual social groups in museums and science centers. Telephone and in-person interviews with 32 staff from 22 organizations (museums, science centers, zoos and aquaria), generated data to document current practices, collective knowledge, and outstanding questions in bilingual exhibit-making. This inquiry into professional practices informed the visitor research component, which involved interviews and observations among 32 bilingual social groups at four science centers/museums. A thematic analysis revealed how bilingual visitors greatly value bilingual exhibits. Bilingual visitors do not have uniform language ability. They fluidly weave together the two languages creating a linguistically dynamic social experience, integrating content and language learning.

Renner has also conducted evaluation in museum settings. Working with Marianna Adams, her studies for the San Diego Natural History Museum explored museum visitors' and non-visitors' knowledge, attitudes, and behaviors related to nature. Renner has used various methods to probe prior knowledge, including mind-mapping, card-sort interviews, and role-playing activities. Under the auspices of the Balboa Park Learning Institute, also working with Adams, Renner trained professionals from twelve San Diego museums to analyze and interpret survey data they collected from their visitors. The study focused on understanding how visitors' motivations and perceived benefits of attending museums varied with age, gender, social group, and other demographic variables.

Renner currently serves as director of San Diego's Art of Science Learning Incubator for Innovation. The Art of Science Learning, ambitious in scale and complex in scope, is creating new models and new tools to promote creativity and innovation in science, technology, engineering, and mathematics by integrating the arts. With funding from NSF's Advancing Informal STEM Learning under the direction of PI Harvey Seifter, three Incubators for Innovation in San Diego, Chicago, and Worcester, MA host multi-disciplinary multi-generational learning communities for one year. During that time, Innovation Fellows participate in workshops practicing innovation processes and skills using the arts, and create new products, services, and learning programs focused on a civic challenge. The community of San Diego proposed and selected as their challenge Water, and the mismatch between regional supply and demand, a challenge of great relevance in this time of severe drought. Directing an Incubator for Innovation mixes the pedagogical, curatorial, and managerial. Although Renner's focus is not on evaluation or research for this project, the Art of Science Learning provides opportunities to consider approaches to evaluation and research in such an unusual, complex extended learning experience.

# Designing Open Badges for Teaching Educational Technology Skills to Inservice Teachers and Students

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## Background of Project and Design Framework

Organizations both within and outside of traditional schooling have long used badging systems to recognize what a person knows (learning), has done (skills), or has become (role within a community). More recently, digital badges (i.e. digital images used instead of a physical badge) have been implemented for the same purposes within educational communities (e.g., Khan Academy) or social networks (e.g., Foursquare). The Mozilla Foundation built upon this movement by creating the Open Badges Infrastructure for issuing and managing digital badges with embedded metadata. This infrastructure is an open and free credential-issuing platform (The Mozilla Foundation, Peer 2 Peer University, & The MacArthur Foundation, 2012), allowing a badge issuer to easily award badges to an earner's digital backpack. Mozilla (n.d.) explained that "the web and other new learning spaces provide exciting ways to gain skills and experience . . . Badges provide a way for learners to get recognition for these skills, and display them to potential employers, schools, colleagues and their community" (Mozilla, n.d.).

More recently there has been a push to distinguish Mozilla Open Badges from traditional digital badges. Since digital badges are nothing more than an image shared digitally, they do not offer the security or assurances that the earner truly deserves the badge. Mozilla's Open Badges provide a digital image, but also include metadata about the issuer's information, criteria for earning the badge, and if desired, a URL to evidence of the earner's mastery. This metadata is sent with the digital image and stored on the issuer's servers. Thus, the Open Badges Infrastructure provides links directly to the students' *evidence* of what they have accomplished (e.g. an artifact they produced), the *criteria* they were assessed against (e.g. a rubric), and *the issuer*, or person qualified to award the badge. Attaching this evidence directly into the credential that the students earn is a powerful way to connect evidence to outcome. When combined with tutorials and resources, badges become a powerful self-learning tool.

## Summary of Current Project

Our project is to design and research the effectiveness of open badges for teaching technology skills to K-12 preservice and inservice teachers. We began this effort by creating the IPT Ed Tech Badges (<http://iptedtec.org>), and have issued dozens of badges already to preservice teachers from BYU and other universities. In our initial conceptualization of the badges (further explained in an article we published, see Randall, Harrison & West, 2013), we have envisioned three levels of badges that teachers could earn. First, a *technology* level of badges where they show they have mastered a particular technology. Second, a *strategy* level of badges where teachers plan how to effectively design strategies for integrating a technology into their teaching. Third, an *implementation* level of badges where they show evidence of successfully integrating their strategy into their classroom.

To date, only the technology-level badges have been designed and implemented. Thus, our project is to first design the second and third levels of badges. Second, to expand the implementation of our badges to include inservice teachers and their students, and third, to research the effectiveness of the badges in motivating and assisting teachers and students to learn technology skills and showcase these skills to employers.

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# Designing for Persistence after Failure

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## Goals of the Research

My dissertation explores how to design digital learning environments that embrace failure and the deliberation and experimentation that learners undergo to learn from that failure. A challenge that arises for designers of learning environments is how to promote the perception that incidents of failure are opportunities for learning rather than simply markers of inability in learners. My research tackles this issue in two projects that bridge prior work done in academic motivation, emotions, cognition, and game design. Games create artificial tests in which players can fail, providing a schema in which challenge and confusion are positive attributes that inspire persistent effort. In applying game design elements to academic learning, an understanding of the reasons for persistence or lack thereof is crucial. Deep and continuous learning does not depend only on amount of persistence but also reasons for persistence. For example, learners can be motivated by their goals for content mastery, personal progress, and/or outperforming others. These goals emerge and reshape as learners interact with environmental factors such as social dynamics as well as physical and digital artifacts. Using science and math games, my research identifies design features that support and hinder the pursuit of different types of goals as well as the persistence of those pursuits.

## Preliminary Work with Organizational Partners

For my work, I have two organizational partners. The first is the Norwegian Museum of Science and Technology. As a visiting researcher at the University of Oslo, I spent half a year collaborating with the university research team and museum educators to develop a heat pump game for the museum's energy of the future exhibition and to collect data to research its impact on motivation and learning. Through conducting interaction analyses (Jordan & Henderson, 1995) with videos of gameplay—and supplementing that data with motivation questionnaires and one-on-one interviews—my colleagues and I have identified game design features that support and hinder the pursuit of different types of goals. Through our analyses, we trace how the social and material environment of the game influences student help-seeking behaviors and how the pattern of such behaviors reflect the stability and change in their goals, providing a marker of persistence.

The second part of my dissertation is in partnership with the MIND Research Institute, a non-profit organization that creates math games. The past three years, the MIND Research Institute has collected student confidence judgments of the correctness of their answers in the math games by asking them if they are sure or not sure of their answers. We have identified procedural and conceptual questions that are likely to elicit incorrect answers reported with high confidence for use in a study with primary school students. In an experiment under development, I aim to induce confusion through making errors on answers reported with high confidence graphically salient and assess how that triggers changes in student learning behaviors such as attention to feedback, strategy use, and persistence. This particular design intervention was chosen because research shows that both adults and children are more likely to correct errors in answers reported with high confidence than errors in answers reported with low confidence in an immediate post-test of factual recall of trivia questions (Metcalfe & Finn, 2012). The question my study addresses is whether this effect extends beyond problems of factual recall to problems that require more complex thinking and whether the saliency of those high confidence errors influences students to make choices (such as employing greater persistence) that can result in deeper, conceptual understanding of math.

This dissertation work is part of my larger goal to integrate insights from different fields to promote productive persistence after failure. It is important to understand not just how much students are persisting but why they are persisting because those goals affect knowledge acquisition and motivation for future learning.

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# Toward a Multimodal Semiotics of Mathematics Teaching and Learning

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## A Problem of Practice: Teaching that Math Notation Has Meaning

Mathematicians understand their discipline to be a method of logical reasoning about abstract mathematical objects such as numbers, sets, and relations between them, through which discoveries may be made with potential implications for our understanding of the natural world. Students, on the other hand, often conceive of mathematics as a collection of algorithmic techniques for manipulating formal notation, disregarding the concepts that those symbols might represent, and teachers and researchers struggle to help them see the bigger picture. To some extent, students' limited view of math is based on a naïve understanding of the notation itself, as students see variables and equations as the object of study, rather than the mathematical objects that they signify. When the map is confused for the territory in this way, learning becomes more difficult as well: "confusions ... can occur when the attention of the pupil is focused more closely on the symbols themselves (i.e. the language itself), rather than on the meanings of those symbols" (Pimm, 1987, p. 19). That is, students are confused because they have learned the syntax of the "language of mathematics," but not its semantics.

Viewed in this way, a fundamental problem of mathematics education is revealed to be essentially a question about language and communication. For this reason, there has been a push for interdisciplinary work that considers mathematics education as an embodied instantiation of multisemiotic discursive practices (Gutierrez, Sengupta-Irving, & Dieckmann, 2010), and that situates the analysis at the intersection of the communicative and the cognitive (Sfard, 2012). The current project answers this call by considering symbolic notation as one among many meaning-making resources in the rich semiotic environment of the mathematics classroom. Through an analysis of the complete multimodal ecology of classroom interaction, including speech, writing, diagrams, and gesture as well as formal notation, we can present a clearer description of the "language of mathematics" of which the notation is only one component. Ultimately, if students can be socialized mathematicians' ways of talking about math, they may come to understand math content better.

## Methods: Ethnography of Communication in the Mathematics Classroom

The current project approaches the social and communicative aspects of mathematics classroom interaction through an interdisciplinary approach that draws on a semiotic theory of multimodal interaction, an anthropological theory of language socialization, and an ethnographic methodology of classroom discourse analysis. Rather than viewing mathematical discourse as combining "special *keywords* ... [and] visual *mediators*, such as numerals, algebraic symbols, and graphs" (Sfard, 2012, p. 2; emphasis added), in effect setting language over and apart from other semiotic systems, this approach allows us to consider both linguistic and non-linguistic signs as complementary representations of a common abstract mathematical object, with meaning emerging from the circumstances of interaction. By describing how different modalities fit together in situated interaction, this research will identify how mathematical communication reproduces ideologies of mathematical knowledge and authority, and how students' use of mathematical communicative practices expresses their own agency with regard to their ongoing process of academic socialization.

The data for this project comes from ethnographic fieldwork comprising participant observation and video recording in one middle school and two undergraduate mathematics classes, lasting for the duration of the Spring 2014 semester. To obtain permission to conduct this research, partnerships were established not only between the linguistics and mathematics departments of the researcher's university, but with a nearby public school district as well. At both middle school and higher education levels, the participants who were selected are already intentionally focusing instruction on ways of communicating mathematical concepts, and it is hoped that the findings from this project will aid partner teachers, as well as others with similar interests, in deepening their students' engagement with this aspect of the discipline.

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# **"Hablemos Sobre Enseñanza/Let's Talk about Teaching": Supporting Conversations about Teaching Practice in Chilean Teacher Networks**

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This is a study of the importance of “problem negotiation” in collaborations between teachers and researchers. The study presents two contrasting cases of negotiation involving two different teacher networks in Chile, each of which was engaged in using a web-based tool intended to facilitate conversation about teaching practice. Problem negotiation is the first, and perhaps most important, phase of the Design-Based Implementation Research (DBIR) methodology (Penuel, Coburn, and Gallagher, 2013). This methodology provides guidance in developing interventions for use in practice that are sustainable and scalable (Fishman et al., 2013).

The study took place in the context of a national reform initiative in Chile that has encouraged the emergence of teacher professional networks. The teachers in these networks come from different schools within a district, and meet face-to-face periodically. I studied two networks that participated in co-designing wiki-based scaffolds to support their conversations about teaching practice (e.g. Cobb, Zhao, & Dean, 2009; Penuel, Fishman, Cheng, & Sabelli, 2011). Several cycles of design, enactment, analysis and redesign were used to enhance the tool to support conversations about teaching practice. In the first network, problem negotiation involved top-down coordination with policy-makers and network coordinator. The researcher introduced the tool, and also mediated its use by participants. Teacher participation was not consistent, highlighting a potential misunderstanding of the problem being addressed through the intervention. In the second network, problem negotiation was more bottom-up, with all participants engaged in deciding the intervention was something they wanted to explore in response to a particular problem. The tool use was more independent and involved active participation, suggesting a better understanding of the problem of practice we were addressing.

This study contributes to our understanding of DBIR (Fishman, Penuel, Allen, Cheng, & Sabelli, 2013) by exploring the negotiation of a problem of practice. The study employs qualitative methods for capturing participants’ perspectives and features of the context that might play a role in the intervention. Using interviews, observations, and document data this study analyzes the process of negotiating a problem of practice and the evidence of commitment and/or differing views to understand how that affected the success of the intervention.

Research suggests that forms of professional development that encourage learning through active participation, with content that relates to subject matter classroom practice, and with a focus on student learning are likely to lead to greater improvements for teachers (Darling-Hammond & Richardson, 2009; Kooy & van Veen, 2012). Developing teacher professional networks for the improvement of teaching through the analysis of practice has been suggested as a generative ongoing professional development activity (e.g. Ball & Cohen, 1999; Borko, 2004). However, developing reflective conversations around practice requires conditions for teachers to focus on specific aspects of practice that do not necessarily emerge from getting together. Moreover, teachers need support for sustaining this type of conversations. Understanding how teachers in networks, and researchers who support them, arrive at agreement on the problem of practice to be addressed can contribute to improving the crucial phase of negotiation in studies involving collaboration researcher/participants.

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# Leadership Development for Collaborative Educational Data Use

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## Background and Goals

The current epoch of data-driven decision-making (e.g., Knapp, Copland, & Swinnerton, 2007) takes a bold stance on the potential of evidence and data to influence educational outcomes, particularly in disadvantaged communities. School districts are partnering with community groups and other stakeholders to create integrated data systems, shared metrics, and data dashboards to better align their efforts and improve a wide range of youth outcomes, including overall well-being, math and reading achievement, and high school graduation rates. Yet, information alone cannot create the individual and collective will necessary to move forward such complex initiatives. Not only do many communities lack the capacity to gather, interpret, and use evidence effectively, but deep cultural, relational, structural, and belief barriers often impede these processes at a fundamental level (Diamond & Cooper, 2007; Nelson, Leffler & Hansen, 2009; Nutley, Walter, & Davies, 2007). Even in exemplary cases where evidence and information provoke discussion and deliberation, it often remains ambiguous what next actions are “prescribed” (Honig & Coburn, 2008). In short, even the best data system can’t change the fact that ultimately, problems are caused – and solved – by people. And for those people to solve their problems, they need to be motivated, educated, and organized – the foundation of leadership.

This research-practice project examines a three-month leadership development experience called the Data Leadership Initiative (DLI), designed to build human capacity to improve the effective use of data and evidence to drive community change. The research goals are 1) To explore how learner self-awareness predicts uptake and recontextualization of tools and routines designed to improve collaborative data use in education; and 2) To examine the relationship between individual uptake of leadership development tools and on-the-ground progress toward data-related goals in learners’ work environments.

## Methods

From a pool of 11 applicant organizations around the United States, we selected five teams of two people each to participate, based on the clarity of their project goals and alignment with each others’ interests. Designed and led by this researcher and supported by a coaching team, the cohort experience began and ended with two-day in-person meetings in May and July 2013, which were bridged by weekly synchronous, online meetings and asynchronous assignments. This design was intended to blend intensive face-to-face experiences with sustained online interaction, supporting participants’ everyday work in their home environments (Ganz & Lin, 2011).

Data sources comprise pre- and post-survey data, including a leadership assessment and questions about aspects of the DLI curriculum and experience; submitted artifacts like homework assignments and reflection papers; responses to short daily surveys asking participants whether they had used any concepts or tools from the DLI that day, and whether they had had any contact with other DLI participants; and recordings of cohort meetings and interviews. The outcome of interest is progress made toward each individual’s stated data-related project goal between May 2013 and April 2014. Using cross-case synthesis (Yin, 2009), I propose to use relevant data from these sources to create an array of data tables comparing features of each participant’s case. These tables which will then be interpreted to identify a typology of “data leadership learning cases.” My primary theoretical proposition is that goal progress is positively predicted by both demonstrated and intended uptake and recontextualization of DLI tools (e.g., processes for eliciting organizational theories of change from multiple stakeholders). Secondarily, I propose that uptake of DLI tools is positively predicted by the extent to which participants were able to recognize and articulate personal leadership challenges with which they were struggling, as demonstrated through written assignments and coaching interactions.

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# Making Learning: Leverage Makerspaces as Learning Environments

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## Goals of Research

Through ethnographic investigation, I seek to answer the question: *how is learning demonstrated in makerspaces?* Specifically, my goal is twofold: 1) to build a comprehensive understanding of how experienced makers approach and complete making activities in makerspaces, and 2) extract implications from this investigation for the design of makerspace-inspired learning environments.

## Background and Theoretical Frame

In response to President Obama's call encouraging youth "to be makers of things, not just consumers of things" (29 April 2009), educational researchers are considering makerspaces as viable alternatives to traditional STEM learning environments. Makerspaces are physical places where members ascribe to a common ethos of hacking, tinkering, and making at the intersection of physical and digital worlds (Anderson, 2012). This shift is fundamentally changing the way educators envision teaching and learning. As a result, making and makerspaces have gained traction in formal, public contexts materializing as the maker movement (Anderson, 2012). This movement contends *making*—an active process of building, designing, and innovating with tools and materials to produce shareable artifacts—is a naturally rich and authentic learning trajectory (Martinez & Stager, 2013). Though learning through making intuitively "makes sense" to researchers, educators, parents, and kids, we lack a deep understanding of how learning *actually* happens in makerspaces.

I draw from constructionist and new literacies perspectives of learning to develop a viable framework through which we can understand makerspaces as learning environments. Specifically, I identify three theoretical convergences on which I build this study: 1) learning is about building relationships with tools and people; 2) making is a way to learn; 3) producing external artifacts is evidence for learning.

## Methodology

I take an ethnographic approach to explore how learning happens in makerspaces by conducting studies at five makerspaces across the country. At each makerspace, I strategically observe and document the *making trajectories* and *final artifacts* of three experienced young makers (15 total) responding to the making prompt: make flow. For making trajectories, I focus on how makers approach the activity, what tools they use, and how they make sense of their process. Further, for final artifacts, I focus on what *stances* (artistic, engineering, or pragmatic) they take and use stance-specific quality measures to compare artifacts. In analysis, I draw from theories of meta-representational competence (diSessa & Sherin, 2000) and representational trajectories (Halverson, 2013), which both mark learning as building the learners' process of understanding of the relationship between concept and external representation of the concept. Suitably, I trace the path from idea to final artifact as a learning process and compare/contrast according to the stance taken up by the maker.

## Current status

I shaped and designed my study using ethnographic work in makerspaces completed with *Learning in the Making* (Sheridan, et al., in press). For example, our pilot studies support the conception of three *stances* toward making: artistic, engineering, and pragmatic. Additionally, the prompt "make flow" has been successfully piloted across a wide range of contexts and populations as a lucratively ill-defined problem space supporting each stance. I will begin collecting data in the Spring 2014.

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# **Science Teachers Making Sense of Reform: Learning Together in Professional Development in a High-Stakes Environment**

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## **Goals of the Research**

The goals of my dissertation research are to identify the shared social resources that science teachers leverage while sensemaking together in a professional development context. Science teachers work in complex environments in which their knowledge of the content, their students, and the organizational practices of their school play a role in what and how teachers organize learning in their classrooms. However, research into science teacher learning in professional development has focused primarily on teachers' knowledge of content and their students' learning and rarely on the relationship between the organizational processes in schools and science teacher learning (van Driel, Meirink, van Veen, & Zwart, 2012). Key organizational processes include the ways in which resources, such as curriculum materials, lab equipment are distributed and learning is structured across and within schools. A focus on organizational processes complicates the common deficit storyline of teachers lacking content knowledge to enact new teaching practices and makes visible other factors that may constrain teachers' practice.

I use the concept of sensemaking to analyze how science teachers collectively work through dilemmas they encounter in their learning. Sensemaking is a concept from organizational theory that describes the process through which individuals reorganize their activity through retrospective and prospective communication with others when they experience ambiguity or uncertainty with changes to their environment (Weick, 1995). In order to understand science teacher sensemaking in professional development, I attend to the following research questions.

1. What dilemmas do the teachers encounter over the course of the professional development that create opportunities for their collective sensemaking?
2. How do teachers engage in sensemaking of those moments of ambiguity and uncertainty?
3. What, if any, solutions do teachers create during the sensemaking process to resolve those dilemmas?

## **Background of the Project**

The data for my dissertation were collected as part of a larger project, *Educative Learning Progressions As Tools for Teacher Development* (ELEVATE), funded by a CAREER grant number 0953375 from the National Science Foundation. The principal investigator, Dr. Erin Furtak of the University of Colorado, assisted by her research team, designed and enacted a four-year research study that investigated how a learning progression of natural selection informed the planning of the evolution unit, as well as formative assessments in natural selection. The project engaged departments of biology teachers at three separate schools in monthly professional development meetings. The professional development supported the teachers in the design and enactment of formative assessment tools based on a learning progression constructed of canonical and students' intuitive ideas of natural selection, or how organisms change over long periods of time. My dissertation will take one of the three schools as a central case to understand teachers' collective sensemaking over the three years of the professional development.

## **Methodology**

I use a case study approach (Yin, 2003) to develop an account of one of the science departments that participated in the ELEVATE project. In order to develop the case, I rely on the central features of sensemaking as defined by Weick (1995) to identify episodes of sensemaking, the resources that teachers use while sensemaking, and any patterns or routines that teachers use during the sensemaking process. Video taped monthly professional development meetings are the main source of data for my analysis. Initial analysis will include watching the videos to identify episodes where teachers recognize and work through moments of ambiguity and/or uncertainty. Transcripts will be developed of the identified episodes, which will then be coded for the resources teachers draw on while sensemaking. Subsequent steps of analysis will include looking across episodes of sensemaking for patterns of teacher sensemaking at the school.

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# **Early Career Workshop**



# Digital Media for Learning and Assessment

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## Summary of Research

My research investigates the design, research, and evaluation of digital media for learning and assessment. Digital media allow for the collection of log data, such as student actions, behaviors, and communications. These data provide observations of learning that are difficult to capture and study in face-to-face and paper-based contexts. The thrust of my research involves studying how we can use these data to understand student learning and assessment. My research goals are (1) to inform our understanding of the kinds of learning and assessment that is capable with digital media, (2) to develop new research methods for evaluating and assessing learning with digital media, and (3) to use these insights to develop engaging learning experiences that prepare all students for future learning, particularly in Science, Technology, Engineering, and Math (STEM) related fields. The theoretical frameworks that guide my work are situated learning (Brown, Collins, & Duguid, 1989) and evidence centered design (Mislevy, Almond, Lukas, 2004). Through design, I aim to take affordance of learning as a social activity while also focusing on the interactions and experiences that provide opportunities for and evidence of learning.

## Immersive Virtual Assessments

I have been researching and developing different iterations of immersive virtual performance assessments in order to understand how we can assess complex skills in situ. In the *Virtual Assessment Project (VPA)*, we developed short virtual summative assessment tasks that attempt to assess students' ability to design a scientific investigation and make a causal explanation. Students were given an authentic science problem (e.g. How did a frog grow 6 legs?) and had to walk around the virtual environment, collect their own data, and build a claim for what was causing the problem. This research was a natural extension of my dissertation research where I designed a framework for designing actions into immersive learning environments. These actions not only provide evidence about the problem to the student, but also can identify students' ability to reason from evidence and misconceptions. My research on virtual assessments allowed me to test this framework. I worked with colleagues to validate the rubrics by comparing them to machine generated algorithms and designed Bayesian Causal Nets to predict students' ability to engage in causal reasoning based on the evidence they encountered in their experiment (tests they ran, data they collected, etc.) and their final claim. We identified places where we could integrate feedback to help students distinguish causal from non-causal data. I also explored different ways to establish validity and reliability of the data and found that the tasks had high reliability and were measuring what we intended to measure. This research provides evidence to the traditional measurement community that game-based assessments have a place in Next Generation Assessments.

## Formative Assessments of Experimental Design

My research findings on virtual assessments led me to explore how we can assess complex skills in open environments *formatively*. I am currently researching undergraduate students understandings of experimental design in an online simulation on natural selection. Students design and run an experiment to test for differential survival in snails. The experiment is very open and in the past there has not been any feedback for students or a way to interpret log data of their actions. I am currently working on a rubric to parse the log data so that we can interpret students' understanding of the task based on their actions. The next step is to explore ways to provide feedback in real time.

## Future Research Plans

To date, my research on assessment has focused on individual students. In addition to my research described above, my future research trajectory involves conducting research on assessing collaboration. I submitted a proposal to NSF to develop and test a framework for assessing collaborative learning in an online game designed to teach biology and mathematics. 'Fun', 'complex', and 'situated in a meaningful context', are words that we don't typically use to describe assessments. I hope to spend the next stage of my career shifting the public perception of assessment and, hopefully, students' perception that assessments can be fun.

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# **Research Summary: Simulations and Games for Science Learning**

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## **Overview of Current Research**

My past and current research falls into two broad and usually overlapping areas: science education and technology-enhanced learning. I started doing technology-enhanced learning research in graduate school with some of the WISE projects. My dissertation was focused on designing and studying a game to teach physics concepts and vector addition. I have since done a lot of work studying the design, use, and efficacy of simulations and games focused on science learning and these and related topics are a major area for my current and future work.

## **Simulation Meta-Analysis**

I recently led a team in conducting and reporting on a comprehensive meta-analysis of K-12 STEM simulations for learning. This work was funded by the Gates Foundation and is part of a larger set of work on game- and simulation-based assessment. We searched multiple databases, sorted through thousands of abstracts and read hundreds of articles. Our final pool contained 59 studies from all over the world, mostly in the domain area of science.

We found that for achievement outcomes, when computer-based interactive simulations were compared to similar instruction without simulations there was a moderate to strong effect in favor of simulations ( $g+ = 0.62, p < .001$ ). This category included 46 effect sizes. For achievement outcomes, when computer-based interactive simulations were modified to include further enhancements (such as additional learner scaffolding and certain kinds of feedback) and then compared to their original non-modified versions, the modified simulations had a moderate effect on student learning over the non-modified simulations ( $g+ = 0.49, p < .001$ ). This category included 50 effect sizes. Outcome measures relating to scientific inquiry and reasoning skills and to non-cognitive outcomes had positive average effect sizes also, but included fewer studies.

## **Games for Learning/Game-Based Assessment**

While my dissertation and post-doctoral research was on game-based learning, I only recently began working on a game-based learning/assessment project again. The project I am working on is using Evidence Centered Design (ECD) to investigate and validate a game-based assessment on systems thinking. We are developing a process and methodology to deal with this kind of complex learning and assessment space that will hopefully be useful for others who are also working in this space.

## **Speech-Based Learning Analytics for Collaboration**

One additional project that I have just started thinking about and planning for is a collaboration with some of our speech technology researchers at SRI. We would like to use student speech during collaborative tasks to determine whether or not students are collaborating well with each other and whether or not teacher intervention is needed. This would greatly help teachers who typically would find it difficult to adequately monitor 8-10 groups of students working simultaneously. This could lead to increased use of computer-supported collaborative learning in classrooms and also possibly eventually built-in automated scaffolding for students. We feel that there is a lot of promise in this idea, but it is in very early stages.

## **Next Generation Science Standards**

The Next Generation Science Standards (NGSS) were released in the spring of 2013 and in the fall we received a grant from NSF to work collaboratively with researchers from Michigan State University, University of Illinois – Chicago, and The Concord Consortium to develop middle school chemistry tasks that are aligned to NGSS. We are using Evidence Centered Design (ECD) for this process and are documenting the approach along the way so that it could possibly be a model for other groups to develop additional tasks. The tasks are technology-based and many may include simulations and/or interactive components.

## **Project Based Inquiry Science**

I am part of a research team that is conducting a large randomized control trial efficacy study of the Project-Based Inquiry Science (PBIS) middle school science curriculum. We are working with an entire district and collecting a large amount of implementation and assessment data over multiple years. My primary responsibility is on the implementation research team where I help plan and analyze the classroom video data that teachers provide as part of the study. In 2013 I also began leading a smaller team focused on the online weekly log data that teachers submit.

# **Collaborative Knowledge Practices in Higher Education: An Analysis of Student Learning in Two Undergraduate Programs**

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This paper examines how students from two higher education programs, teacher education and computer engineering, respectively, become enrolled in and adopt the knowledge practices of their prospective profession through collaborative projects. The study focuses on understanding how students engage in these knowledge practices and how the study programs facilitate the students' participation.

In recent years, higher education programs are challenged to provide opportunities for learning that prepare students for taking part in professional knowledge practices and the competencies required to deal with knowledge-based work. The learning environments are becoming increasingly complex, and learning to work, i.e., understand, assess, apply and generate knowledge is becoming an essential requirement (Goodyear & Zenios, 2007). While there is agreement that such types of learning are beneficial, they remain complex and challenging for students. In order to support and design complex learning activities, there is a need for in-depth understanding of these knowledge practices and their complexity, in terms of processes, products, resources, and their interdependence. There exist, however, little research that addressed these aspects specifically. A number of empirical studies (e.g., Muukkonen & Lakkala, 2009) have pursued research that conceives of learning as an activity that involves addressing complex knowledge-based problems, which require collaborative inquiry and knowledge construction to reach appropriate solutions; findings showed that such complex processes involve a focus on shared understanding, generating knowledge and joint actions to elaborate on ideas. Studies of research-based learning provided some insights into how research-like activities have the potential to transform students from course-takers to producers of knowledge (Lambert, 2009).

The theoretical framework emphasizes the social, constructive nature of learning (Valsiner & Van der Veer, 2000). It depicts the mechanisms through which knowledge is produced and circulated, but also procedures, ideas, and attitudes (Knorr Cetina, 1999). Knowledge practices and actions emerge in this social context in which interaction is paramount. In the same context, the notion of epistemic (or knowledge) objects (Knorr Cetina, 1999) refers to question-generating and complex entities that have the potential to trigger inquiry and further elaborations on knowledge. For design purposes, the idea of learning in collaboration through dynamic, emerging interaction based on fluid structures will be explored. Organizing learning in a communal knowledge space that allows for flexible collaboration, dynamic negotiation, and the sharing and co-construction of knowledge (objects) opens up new alternatives for designing knowledge-driven learning.

This project will employ qualitative methodology, namely, comparative case studies (Creswell, 2007). In the first explorative iteration, courses will be examined with a focus on existing processes and practices. The second iteration will include adjustments to the course design, following principles of design-based research. The collected data aims to reflect the nature and distribution of activities across the length of the study units and across levels (individual, group, and institutional). The data set will comprise: recordings of group discussions, online correspondence, drafts and knowledge products, group interviews, focus groups with teachers, videotaped lectures, course documentation. The targeted knowledge practices and learning processes are complex, rich, sometimes ill-structured, and have temporal aspects deemed important. The data analysis will employ: a set of qualitative analysis methods (i.e., analysis of discursive interactions, qualitative content analysis and document analysis) that will feed into the general outcomes at different levels; and mapping the trajectories of learning and creating an integrative view of the processes unfolding in different spaces and across time. The analyses will be focused on depicting: a) how students engage and navigate towards appropriating the knowledge practices of their domain of expertise; b) what the students construct and elaborate upon, mainly visible in their knowledge products (objects), and how they employ knowledge resources; and c) how students conceptualize the knowledge culture of their domain of expertise and how they identify themselves as prospective professionals with its knowledge culture.

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# Social Aspects of Legitimate Peripheral Participation

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In my work, I attempt to provide a better understanding of situated learning in “natural learning settings”, focusing on social aspects of and related to learning. The concept of legitimate peripheral participation in communities of practice (Lave & Wenger, 1991) is the central theoretical foundation of my work. From a methodological perspective, Social Network Analysis is one of the core methods I am using.

My work started with the attempt to take a closer look at the question, what exactly happens during legitimate peripheral participation, and if there are recurring social strategies how community members structure newcomers’ learning experience. In this first study, we were able to identify certain *participation support structures* that were used in several self-organized communities of university students (Eberle, Stegmann, & Fischer, 2014). Currently, I am working on two projects which further extend these findings.

## Access to Community Knowledge in a Scientific Community

This study is designed to investigate more closely how the participation support structure *access to community knowledge* influences newcomers’ and more experienced members’ participation in a scientific community. We collected data on different social aspects of participation during two face-to-face events of the scientific community. During the events, all participants wore RFID tags to measure who interacted with whom at what point in time and for how long. Additionally, the participants filled social network questionnaires about their previous collaborations with other participants and their plans for future collaborations. The participants were divided in two groups; the experimental group received a brochure with information about the other participants, while the control group did not receive this brochure. The first scientific event we observed was in 2011 and for this dataset we have already preliminary results, indicating that newcomers without access to community knowledge are disadvantaged compared to experienced members regarding the amount of persons with whom they make plans for future collaborations. When newcomers are provided with access to community knowledge, however, this disadvantage disappears (Eberle, Stegmann, Lund, Barrat, Sailer, & Fischer, 2013). Currently, we are looking on the social dynamics that happened during this scientific event. Furthermore, we collected additional data on actual collaborations later on by conducting a Google-Scholar search on co-authored papers since the event in 2011. During a second scientific event of this community which took place in 2013, we did a replication study and are currently analyzing this data accordingly.

## Development of Early Career Researchers

My second current project is about the development of early career researchers’ careers based on the experiences they have made as PhD students. Within this large collaboration project between several German universities, my focus is on the role of being and feeling as part of a scientific community for the scientific self-concept and on future career paths into or away from academia. This project is based on Early Career Researchers in Germany, where a major change in the training approach of PhD students currently takes place. The traditional German PhD training approach can be described as a master-apprentice model that is individually shaped by a particular professor and PhD student. This model is very close to the legitimate peripheral participation approach, while the current trend goes more in the direction of formal schooling, with PhD students taking classes and having supervisory teams. From a theoretical approach, both models have benefits and disadvantages, however, empirical data on outcome differences is not available so far and we will closely pay attention to the question how the two PhD training models affect outcomes of the PhD phase and later career development. Within the study, a longitudinal panel study, qualitative interviews, and document analysis are planned.

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# Scaffolding Undergraduates' Argumentative Reasoning

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## Summary of Research

My research focuses on the design, study and assessment of collaborative learning environments aimed at improving students' argumentative reasoning and understanding of domain knowledge. This includes exploring the many affordances of online learning spaces and how they might be systematically leveraged to cultivate learners' collaborative, reasoning and analytical skills. Along with a focus on innovative instructional design, I am interested in advancing understanding of the outcomes of design on student learning processes through the use of *in vivo* experimental design models. I am presently exploring how training in argumentation influences college students' reasoning about and understanding of complex psychological concepts.

## Theoretical Framework

Grounded in socio-cultural and cognitive perspectives on learning, my current research focuses on how learning the skills of argumentation can improve college students' inter- and intra-personal reasoning skills and enhance their ability to *think with* scientific domain knowledge. This line of work stems from previous analyses of distributed small group leadership in online interdisciplinary collaborative groups of pre-service teachers and elaborates the topic of my dissertation study. My most recent completed study along this line explored the systematic design and study of a week-long module aimed at improving the quality of undergraduates' arguments. This work was guided by the theoretical views of Toulmin (1972) who introduced the idea of argumentation fields, the idea (briefly stated) that argument components and qualities are not universally generalizable but must be reflectively adapted to contexts. Thus Toulmin's perspective denotes a 'sweet spot' between absolutism and relativism that is useful in framing instructional approaches and has the potential to promote enduring understanding for learners.

## Methodology

Most recently, my research used an *in vivo* experimental design (e.g. Aleven & Koedinger 2002). The broad goal was to explore the effectiveness of a week-long training unit in analyzing arguments prior to content learning. *Adventures in Argument* was evaluated as an efficient and viable alternative to often time-consuming immersion models used in teaching science.

The context of the study was an online section of Human Abilities and Learning (HAL Online). In the treatment manipulation, Trained Argumentation with Modest Scaffolding (TAMS), learners read about sophisticated science concepts from cognitive and neuroscience research and were expected to gain understanding and practice integrating these ideas to support decision making in individual and group problem-based learning activities. TAMS was compared with an ecological control condition that received an alternative module to *Adventures in Argument* but was otherwise identical to the treatment manipulation.

To analyze the data collected, I used a mixed quantitative and qualitative approach to data analysis. Statistical analysis followed procedures for nested designs recommended by Kirk (2012), and qualitative analysis followed procedures for quantifying qualitative analyses recommended by Chi (1997).

## Conclusion

Initial results of this research indicated benefits of training in argumentation on student learning processes and outcomes. TAMS exerted strong influence on how deeply and thoroughly students processed, were accountable to, and integrated instructional resources. Moreover, students who received the training performed significantly higher on a test of scientific literacy than those who were in the ecological control group. The study contributes to a discussion on how to optimally approach argumentation as pedagogy and provides support for the direct training approach, at least for undergraduate learners in online courses that employ argumentative pedagogy.

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# Transforming Technological and Scientific Practice: A Research Summary

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The increasing ubiquity of geospatial tools, open source software, mobile devices, and social media sites is not just changing the technological and scientific practices of professionals; this rapidly expanding terrain of accessible technology has supported non-professionals – even young people – in transforming scientific and technological practice to address their own daily needs. In my research, I have explored this emerging and technologically-dense space, looking closely at the role of digital media in the lives of children, youth, and adults through ethnographic and mixed method case studies, classroom and community-focused design studies, and the development and study of undergraduate courses for pre-service teachers. I am most committed to the notion that young people, in collaboration with one another and emerging technologies, have the potential for producing new techno-civic practices that address and influence practical, “on the ground” issues. In my work, I argue that young people’s interest and familiarity with new and mobile technologies remain untapped resources for formal and other designed learning spaces. Wisely leveraging these tools for young people’s learning and engagement requires more ethnographic and small-scale design research about how children and youth use mobile computing in the more informal, transitional spaces of daily life. Capturing and making sense of these flows, or “daily rounds” – made even more dynamic in interaction with mobile technologies – demand new, mobile research methods and an updated theoretical lens of the spatio-temporal aspects of learning. In the work that follows, I treat learning as distributed, not just across individuals and resources, but across particular places, biographies, imagined future identities, and all of the sense-making modes of the body.

In my current work, I am focused on how children independently elect to use digital media and how technology can be leveraged to make learning relevant to a diversity of young people across formal and informal environments. In my project with the LIFE Center and the Joan Ganz Cooney Center (*Learning Across Networked and Emergent Spaces*, Reed Stevens, PI), I have designed and am implementing a study that captures what nine to thirteen year old children do with digital media in and around their homes, and how technology influences family interactions. We are particularly interested in moments of joint media engagement where family members come together to co-view media content, and how JME is changing with the ubiquity of mobile devices in homes. Participating families are from a range of racial and socioeconomic backgrounds in the Chicago area; these households represent a diverse range of how children and parents use digital media for learning and engagement. I am collecting detailed video recordings of family practices around media, conducting parent and child interviews, doing experience sampling over the phone with focal children regarding their media use, and mapping technology “hot spots” using a geographic information system. Focal children are wearing head cameras to capture “on the move” media use, and parents are participating in a nationwide survey created by the Cooney Center about the perceptions of “educational media.” Data collection is still underway, but preliminary findings suggest that *mobile* devices significantly influence the nature of JME in that co-viewing arrangements are much more fluid and regularly emerge during activities that used to be considered “unplugged” (e.g., piano lessons, grocery shopping).

This mixed methods approach to understanding how a diversity of children engage with technology is a throwback to my dissertation project at Vanderbilt (a component of the *Tangible Math Project*, Rogers Hall and Kevin Leander, co-PIs). This research was a social design experiment in which I co-created and studied a new curriculum for inner-city youth living in a “mobility desert” to learn (counter) mapping practices with geospatial technologies like GPS and GIS software. The theoretical and design conjectures for this new curriculum were based on findings from a year of ethnographic research conducted with urban planners and residents participating in a community planning process. I worked closely with the director of a local youth-serving organization, urban planners, and the parents and youth of a HOPE VI neighborhood to support young people in re-imagining and re-presenting a new and different story of their community. The director of the program and I expanded and re-mediated the mobility of neighborhood youth with old (e.g., bicycles) and new (i.e., GPS devices and head cameras) technologies through activities like GPS drawing and historical neighborhood geocaches. These new experiences and youth-captured data were the basis for young people to counter-map their neighborhood with urban planners and local stakeholders. By the end of the study, counter-mapping emerged as a new theory of social action and spatial change; counter-mapping created a new collaborative space for learning and interactivity for both professional and younger and older residents that brought together cognitive maps of the neighborhood, professional classifications of space, value-laden feelings of place, older and newer technologies, and embodied responses for imagining new, more equitable spaces for daily life.

# Searching for the 'Dialogic' within the Dialogue: Temporal Analysis of Teacher Orchestration in Technology Enhanced Elementary School Classrooms

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My research interests fall within the theme of interaction within the classroom with a particular focus on teacher orchestration and technology enhanced learning. I am interested particularly in the interaction of teachers with students. I explore how teachers and students respond within the process of orchestration of classroom learning and how this may impact upon their success at tasks.

My research begins with the premise that learning takes place within the context of a series of dialogic interactions. The meaning which individuals make during these interactions is an intramental process mediated by their understanding of language. Such meaning is also temporally and contextually dependent. Within interactions there are numerous assumptions made intramentally by each participant as to the nature of their intermental interaction. Implicit assumptions made by the teacher; the passing theories which they develop which relate to their students as groups or individuals, impact upon how the teacher behaves in a given situation.

Drawing on Vygotsky's ZPD, orchestration is a continuous process of balancing factors present in the classroom over which teachers have a degree of control. It is this process which precipitates the interactions in which learning takes place. When orchestrating a classroom activity, teachers vary the register in which they interact with children. Such interactions, verbal or non-verbal, can be directed at an individual, a group of students or the whole class.

It is the interactions between the teacher and students (as individuals, groups or as a class) which formed the basis for my doctoral research, part of the SynergyNet project (<http://tel.dur.ac.uk/synergynet/>); a large interdisciplinary project funded as part of the UK's Teaching and Learning Research Programme (TLRP) by the Economic and Social Research Council (ESRC) and the Engineering and Physical Sciences Research Council (EPSRC). The overall aim of the project was to create an integrated classroom where technological processes did not get in the way of the pedagogical processes.

My study was enabled through two new technologies; firstly, orchestration controls of the classroom, allowing the simultaneous operation of multi-touch tables all the tables and the interactive whiteboard by the teacher. The second was the SynergyView data analysis tool. Which allowed for the combination of multiple audio-visual and table-usage data streams with transcription in a linear, time-line, format (see figure 1). Looking at the output from an activity with reference to the external assessment standards of the education system in which the activity takes place (in the English context, the level descriptors for attainment in each of the curriculum subjects), gives an external measure of the effectiveness of this process of orchestration and interaction. Looking at teacher and student interactions and their constituent utterances gives an observable indication of the thought processes which are taking place intramentally.

My current research focuses on two questions. Firstly, to what extent is teacher interaction a contributory factor to group success in collaborative activity and to explore the characteristics of supportive interaction, particularly its initiation and its content focus. Early results suggest that there are significant differences in the number and character of the interactions which they initiate with the teacher compared to less successful groups. The second question relates to the common practice of mini-plenaries; brief whole-class level discussions instigated by the teacher during a group-working section of a lesson. The triggers which cause teachers to initiate them relate to the passing theories developed by the teachers about the progress and needs of groups or individuals in their class. I am currently investigating the behaviors of teachers prior to the instigation of these plenaries to explore the reasons teachers seek to implement them. This will be followed by an analysis of their potential impact upon subsequent group success.



Figure 1. The SynergyView tool

# **Undergraduate Students' STEM-Based Computing Practices**

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## **Introduction**

Dr. Magana's research interests are centered on the integration of cyberinfrastructure, cyber-physical systems, and computational modeling and simulation tools and methods for supporting disciplines in Science Technology Engineering and Mathematics (herein called STEM-based computing). Through these technologies her educational research goal is to help undergraduate learners: (a) enhance understanding of complex phenomena in science and engineering and (b) engage in scientific inquiry learning, problem solving, and innovation processes. She has investigated two bodies of work that are reflected in the research objectives described below: (1) investigation of the use of computation for problem solving and design in undergraduate education and (2) research on computing and cyber-physical systems affordances for learning and engagement in STEM fields.

## **Research Objective 1: Identify how to Effectively Use of Computation for Problem Solving and Design in Undergraduate Science and Engineering Education**

Computation is a form of representational media that is essential for the analysis and design of solutions to modern technological needs. Specifically in engineering domains, computation requires knowing when, why, and how computation methods work and when they do not, and applying or modifying existing numerical methods or methodologies to successfully solve problems or design solutions. Higher education, however, is not keeping pace with equipping undergraduate engineering students with computation literacy needed to solve problems in an existing or new application field. Current educational strategies at the undergraduate level frequently treat computing as a narrow technical tool that is commonly applied in isolation from related disciplinary topics. Therefore, in the same way as (a) computational thinking is best realized in domain-specific and personally relevant contexts, and (b) computational literacy has been identified as an effective medium for exploring other domains such as math and science; we argue that computation in engineering can enhance student inquiry and problem solving processes by supporting (i) representational fluency providing access to the underlying mathematical and computational model (ii) comprehension of behavior of complex systems and (iii) prediction of behaviors of new designs. Dr. Magana contributes to the body of knowledge of disciplinary-based computing education research through investigation of how learners' integrate computation contextualized in authentic interdisciplinary problems. The guiding research question is: *What are qualitatively different ways by which individuals experience computation while modeling, designing and problem solving?*

## **Research Objective 2: Investigate how Computational Tools and Cyber-Physical Systems Affordances Promote Authentic Practices in STEM Fields**

Advances in computing contribute to science and engineering discovery, innovation, and education by facilitating representations, processing, storage, analyses, simulation, and visualization of unprecedented amounts of experimental and observational data to address problems that affect health, energy, environment, security, and quality of life. These advancements have resulted in computational tools and a deluge of scientific data, and future scientists and engineers need to be prepared to exploit them to generate effective knowledge and solutions to human challenges. However, a well-recognized shortage of scientists and engineers who are adequately prepared to take advantage of, or contribute to, such highly interdisciplinary, highly computational scientific challenges is evident. Thus, future engineers need to be prepared adequately for the complex and rapidly evolving global challenges with knowledge and skills that go beyond mere theory — knowledge that is typically gained by generating, manipulating, analyzing, processing, simulating, and visualizing materials, energy, processes and information. To this end, we must engage learners in meaningful learning experiences where it is necessary to adopt a "practice perspective." In a practice perspective the focus of learning is on participation in authentic experiences, where learning environments: (a) are personally meaningful to the learner, (b) relate to the real-world, and (c) provide an opportunity to think in the modes of a particular discipline (Shaffer & Resnick, 1999). Dr. Magana's work develops new knowledge of how individuals benefit from or struggle with the use of engineering and computational tools in the context of authentic modern engineering practices. Thus, the guiding research question is: *How do students use computational tools and cyber-physical systems to facilitate learning in the context of authentic practices?*

## **Conclusion**

In summary, the primary focus of Dr. Magana's work relates to a research-based and educationally-sound novel approach for educating and training the next generation of computing and computing-intensive related fields' workforce. Her findings from educational research at the intersection of computing, science and engineering will boost the chances for discovery and innovation success and will help the Nation take advantage of the role of computing and computational tools sooner, better, and with greater confidence.

# Integrating the Epistemic, Conceptual, and Social Aspects of Science in Elementary School Instruction

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Science education research has shifted toward a characterization of science as practice, a view that calls for integrating the conceptual, epistemic, and social aspects of science in instruction. This image guides recent consensus documents (e.g., the National Research Council's (2011) *Framework for K-12 Science Education* and the *Next Generation Science Standards*). It sets a challenging agenda for research in Science Education and the Learning Sciences. First, we have much to learn about how to initiate novices into scientific practices. When practices are introduced into classrooms, students can adopt them without understanding their functions or using them flexibly. Therefore, researchers increasingly stress the importance of designing learning contexts that establish a need for practices and characterizing the development of practices over time. Second, we must develop more precise ways to characterize the relationship between scientific practices and the development of scientific knowledge.

My work is grounded in the understanding that practices and knowledge co-originate in meaningful activity (Vygotsky, 1978). Ways of talking, acting, and using ideas have stable expressions in established disciplines, but their forms and functions are interactionally accomplished in communities as members attempt to align their behavior and accomplish goals. Therefore, I seek to establish contexts in which the *functions* of scientific practices are sensible to students and to analyze how they come to see a need for these practices and how they refine them over time as they develop classroom epistemic cultures (Knorr-Cetina, 1999).

## Research to Date

This perspective informed my dissertation work, a three-year design study conducted with one third grade teacher and three cohorts of her students. I engaged students in developing explanations of the “wild backyard,” an overgrown area behind their school. I used their activity as a context for exploring the co-development of modeling practices and ecological knowledge. The design principles that guided this work were informed both by the Science Studies literature and principles for fostering disciplinary engagement. Specifically, I engaged students in working with representations of the backyard that simplified its complexity and highlighted important variables and relations; problematized the relations between the representations and the backyard; positioned students to construct and critique those relations; and engaged them in extended periods of activity around each representation.

This work has allowed me to develop a more refined understanding of the development of scientific practices and content knowledge. It demonstrates the conceptual affordances of scientific practices that young students are usually not invited to participate in, such as operationalizing variables and exploring how an experiment represents a messy, real-world phenomenon. Second, it explores specific mechanisms by which students develop new understandings as they participate in these practices, namely differentiating ideas, relating ideas, and calling on ideas as mechanisms. Third, it underscores the importance of developing learning environments in which forms of uncertainty experienced by students, teaching practices, students’ intellectual roles, and available conceptual resources are explicitly designed to be mutually supportive.

## Future Directions

I am interested in continuing to explore the practices that appeared to be sensible to the students in my dissertation study and also had strong conceptual payoff, e.g., considering an experiment as a model of a phenomenon, choosing variables, and deciding how to see those variables. I want to understand how curriculum materials provide or constrain opportunities for these forms of practice, how teachers learn to “see” and capitalize on these opportunities, and how to develop effective forms of support for teachers. One issue that will be central to supporting these practices is dealing with how best to reify them so that they can be understood and adopted by teachers. The danger is that reifications are easily lifted out of the context of activity and scientific communities that lend them meaning, so that they become framed as procedural skills. To this end, I will continue to work to understand how design can focus on developing activity contexts within which the functions of scientific practices are meaningful to both students and teachers.

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# Adding a Human Touch to Personalized Digital Learning

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## Overview of Research

Understanding the social context of learning has implications for educational equity. The advent of widespread low-cost computing enables us to deploy proven successful technologies to students who previously had limited access to educational resources. In many cases, the models of appropriate behavior and student identity these technologies espouse are largely unconscious choices by the designer, and may contain unintended assumptions about culture, ethnicity, and gender. Given that most systems are developed and evaluated in middle-class North America and Western Europe, the implicit values and practices they embrace may not conform to the cultural norms of other contexts, potentially to negative effect. Thus, we must ensure that we examine our assumptions, as technologists increasingly become the gatekeepers of widespread education.

Personalized learning systems are one such technology with the potential to transform education worldwide. Such systems have been shown to significantly increase learning gains with the help of highly individualized models of students' knowledge. With an international team working with local researchers, I am investigating the effectiveness of an off-the-shelf intelligent tutor for learning algebra developed in the U.S. With observation, interviews, learning assessments, and log data, we have currently investigated use of the technology in eight international school sites. An example finding was the much greater propensity of students in our Latin American sites to collaborate closely, engaging in interdependently-paced work very frequently conducted away from their own computers. This threatened the core assumption of personalized learning systems –that learning is individual– and rendered the sophisticated, personalized models inaccurate (Ogan, Baker, & Walker et al., in press). These types of findings do not mean that we should abandon such successful technologies. However, the models we build can only be as good as our assumptions about the data. In order to achieve the full benefits of personalized learning, we must rethink underlying expectations for data collection and system design. For instance, our studies suggest that incorporating low-cost sensors can aid systems in better determining the context of use and active users. Technology designers could then implement culturally appropriate instantiations of their personalization algorithms (e.g., collaborative knowledge-tracing, help-seeking, and adaptive scaffolding) that take advantage of this contextual understanding (Ogan, Walker, & Baker et al., 2012).

Virtual agents as a learning technology may even more directly embody cultural assumptions. Often reflecting the developers' own identity, most pedagogical agents have European-American skin color, clothing, and language (with some notable exceptions). However, with rapid changes to the cultural makeup of the United States, soon the majority of students will not share this identity. I worked with White urban elementary science teachers whose students are speakers of a different dialect: African American Vernacular English (AAVE). In an experimental trial, we varied the dialect in which science content was presented by an agent. AAVE-speaking students who heard an AAVE-speaking agent believed it was significantly less intelligent than those who heard a Standard American English speaker presenting identical science content. Yet, these students learned more science content from the interaction (Finkelstein, Yarzebinski, & Vaughn et al., 2013).

In a participatory design process, I worked with these same teachers to uncover key perceived responsibilities that educators believed they were tasked with in a multicultural classroom, and how those needs were or were not supported by existing technologies (Ogan, Finkelstein, Yarzebinski et al., in press). For many students, the assumption that students look or speak like most designers or teachers is not met, revealing a complexity of cognitive and socio-emotional issues that should be addressed, and for which teachers feel unprepared. Careful technology design may be an appropriate supporting solution to these issues. Through its adaptive nature, technology can act as a bridge between worlds that are often difficult to connect: that of the student, the teacher, and even the technology designer.

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# Learning and Becoming in Practice

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## Learning and Becoming in Practice

Over the past two decades, the field of learning sciences has learned much about how to design learning environments in a way that allows the actors who engage in them to learn various practices of interest. Despite these advances, the modal learning environment in our schools has changed very little, if at all. This is particularly salient in mathematics classrooms. In these specific environments, skills and concepts continue to be decoupled from the practices in which they are used. This type of “school mathematics” severely constrains students’ opportunities to learn and identify with the actual practices of mathematicians. This is problematic, especially for populations of children who deeply depend on school for their opportunities to learn and identify.

The notion of *Learning and Becoming in Practice* is one that foregrounds the interactive systems in which individuals participate. These interactive systems, which I refer to as learning environments, largely enable and constrain a student’s opportunities to learn and become a certain kind of person. Thus, if we think about who we are and what we know as primarily resulting from what we have experienced, then what children experience in their “schooling” becomes a matter of paramount interest. When this interest is investigated, we find children engage in many rather inauthentic, and frankly irrelevant, experiences. That is, we find children immersed in learning environments that are at odds with much of what the learning sciences tell us about how people learn.

## Current Research Overview

My research tends to focus on how different learning environments enable or constrain opportunities to learn and identify, and I tend to investigate this focus in elementary mathematics classrooms. Three areas of interest usually appear in my work: teacher-student discourse, notions of poverty, and education policy.

### Student-Teacher Discourse

Within a given learning environment, the discourse that occurs between actors is of great interest to me. Through discourse, actors within a learning environment are positioned into, and take up, identities somewhere along a continuum of agency and passivity. This has enormous implications for learning, but also for equity. True democracy involves a specific type of discourse: engaging in dialogue, questioning the decisions of others, articulating your thoughts, the right to unrestricted discussion, and so on. If certain populations of students are not given an opportunity to participate in these practices while in school, then certain populations will continue to be left out of the democracy. Like any skill, people need repeated participation in these practices to become an expert. And, like any skill, those who perform them well are noticed, and those who perform them poorly are pushed to the margins. Thus, much of my current research analyzes how the discourse within a learning environment enables or constrains opportunities to learn and identify, and how these opportunities are distributed across different populations of students.

### Poverty

I am rather unsatisfied with current discussions that focus on education and poverty. In these discussions, poverty is usually conceptualized as lacking resources (e.g., effective teachers, good schools, money). Focusing only on the resources, or lack thereof, that an individual has makes it very difficult to understand why traditional educational reform has failed to reach its ambitious goals. In my writing on the association between poverty and educational outcomes, I try to encourage the field of education to view poverty as two-dimensional: (1) the resources that one has, and (2) one’s capability to convert those resources into their intended benefits. I refer to this as the capabilities perspective, and I confess that this conceptualization, too, is incomplete. Notwithstanding, for those concerned with how improved resources will effect a learning environment, I believe this perspective is much more useful than the traditional resource-based perspective (which a rather robust literature suggests does not work).

### Education Policy

With a focus on learning environments, my research often naturally investigates issues of education policy. For example, I am currently investigating education’s obsession with teachers who have high value-added estimates, and the field’s erroneous belief that high value-added estimates are a good proxy for effective classroom teaching. This unfortunate misunderstanding of value-added estimates has led to impoverished learning environments that provide little opportunity for students to learn or identify with any content or practices not on the test, and even less opportunity to explore their own interests. The notion of *Learning and Becoming in Practice* suggests that these impoverished learning environments will produce impoverished learners.

# **Climate Science in Three Part Harmony: Conceptual, Epistemological and Social Learning Gains**

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## **Background**

The Intergovernmental Panel on Climate Change (IPCC) released the fifth assessment report in September 27, 2013 with new evidence on the climate system and human impact on a changing climate. The panel came to a conclusion that “ Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia.” (p. SPM-3). Although there have been hypothetical and empirical research studies on what and how students should learn climate science concepts during K-12 education (e.g., Shepardson et. al., 2009; Mohan, Chen & Anderson, 2009), there remains a dearth of studies on college students’ learning of climate science topics. The few studies done with college students informed us on the misconceptions that remain at that level such as: short-term and local weather events are evidences for climate change; global warming is caused by ozone layer depletion; acid rain is a result of global warming; and pollution is directly related to global climate change (Lombardi & Sinatra, 2010; Aslan, Cigdemoglu & Mosaley, 2012).. This paper aims to conduct an exploratory study looking at college students’ background knowledge on climate science and the way they communicate and practice their knowledge. By focusing on the harmony of conceptual, epistemic, social components of learning, we ask the following questions for our study:

(1) What are the expectations of the college professors on students’ background on climate and climate change?

(2) What are college students’ conceptual, epistemological and social levels of understanding climate science?

(3) How does students prior learning gains affect their learning processes in their college classrooms?

## **Methods**

This study will be designed as a qualitative exploratory study that will be completed in three related sub studies.

### **Study#1 College Professors’ Expectations**

The participants will be college professors who teach climate science as a part of their courses in three universities. The data from the college professors will be collected through guided-interviews. These interviews will be audio recorded and the audio recordings of the participants’ responses will be analyzed by using inductive comparative pattern analysis (Patton, 2002).

### **Study #2 Understanding Students’ Background Prior to College Classrooms**

The participants will be students who are enrolled in the courses that include the climate science topic at three universities. PI and co-PI will develop open-ended assessment prompts by revising the existing resources to evaluate students’ conceptual understanding, interpretation, analysis and representation of climate science data and the argumentation structure in their argumentative writings about climate change (e.g., Berland & McNeil, 2010; Songer, 2011).

### **Study #3: Case Study to Understand the Learning Processes**

I will observe the Environmental Geology (GEOL 305/505) course offered at Towson University during the spring semester of 2015. Students taking GEOL 305/505 are predominantly environmental science and geology majors or pre-service Earth and Space Science majors. The student enrollment varies between 16-20. I will collect data by video recording the lessons, taking field notes, collecting students’ artifacts and recursive informal interviews with the instructor and the students. Analytical tools from sociolinguistics (e.g. transcripts) will be used to organize and prepare the data for discourse analysis (Gee, 2005; Kelly & Chen, 2005). The analyses will provide examination of the discursive moves between the instructor and students as well as students and students.

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# **Epistemic Thinking and Evidence-Based Reasoning with Multiple Information Sources in Health Decision-Making**

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Contemporary society faces a paradox: Although *access* to information is prevalent, information is *inaccessible*, because it is massive, conflicting, indeterminate, and requires specialized knowledge. This paradox raises key questions for researchers who study cognition, because it demands that lay people utilize knowledge and skills that traditionally have been the realm of scientists and other specialized experts. Specifically, understanding of evidence entails understanding disciplinary practices and norms. Moreover, integrating conflicting evidence is necessary for generating counter-arguments and reaching decisions. The way people think about knowledge and knowing (epistemic thinking) plays a central role in learning and reasoning processes with online information sources (e.g., Barzilai & Zohar, 2012). For example, people who think that they have to justify their claims, will tend to weigh evidence from multiple online information sources. Thus, productive evaluation and integration of multiple information sources both requires knowledge of scientific standards and practices and is related to learners' epistemic thinking. It is not clear whether lay people have the requisite knowledge and skills to use online information sources that report scientific evidence productively in everyday decisions. Therefore, we need to understand how lay people engage in such tasks and which factors facilitate or impede these processes. The proposed research aims to advance our knowledge of such factors.

Although evidence-based reasoning is the essence of scientific thinking, lay people tend to *neglect* or *exclude* evidence that contradicts their theory (e.g., Chinn & Brewer, 1993). Previous studies have also shown that people find it difficult to, and rarely evaluate the trustworthiness of information sources and the content of information sources. Therefore, it is highly important to understand what ways of thinking and what kinds of skills and practices lay people spontaneously employ when they are confronted with contradicting evidence. In our research we will examine how young adults utilize scientific evidence from multiple online information sources to make scientific decisions. We will also examine the role of prior knowledge and the ways people conceive knowledge and knowing, aiming at shedding light on the role of epistemic thinking in reasoning processes and scientific decision making. We will employ Kuhn's theoretical framework to examine conceptions of knowledge and knowing (Kuhn & Weinstock, 2002). Briefly, this developmental model presents three epistemic perspectives: absolutism, multiplism and evaluativism.

This research will be set in the context of *health decision making*. Health information is a common search goal among lay people. People searching for health information seek to answer their health-related questions and to make informed health decisions. However, they are often overwhelmed by the amount of information and by conflicting evidence. Moreover, as Kienhues and his colleagues (2008) show, low-quality health websites are as common as high-quality health websites.

Our research is aimed at investigating how individuals interpret, evaluate, and integrate evidence from multiple online information sources in the process of health decision-making. We are interested in the ways in which people attend the reporting of findings and data and to information concerning experimental design. We are further interested in examining how attending to evidence plays a role in their reasoning and decision making. Finally, we wish to understand the role that epistemic thinking, and prior knowledge play in this process. This research will advance our understanding of the requirements of contemporary everyday reasoning by explicating how lay people can employ evidence-based scientific information from multiple online information sources. Previous research focused on how people reason with information sources that present the outcomes or conclusions of scientific studies but the scientific evidence has not been the focus of attention. Therefore, prior research did not delve deeply into the ways in which lay people attend to data and scientific procedures. The proposed research will extend our knowledge by identifying the factors that facilitate or impede reasoning about scientific data and research designs and procedures. In addition to this contribution to theory, this research may also inform science education (especially health education) by pointing to the types of knowledge and skills that lay people need in order to use online scientific information productively. It may also inform science communication by suggesting the level of presentation that creates a balance between accessibility and rigor for evidence-based reasoning in everyday decisions.

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# **Listening and Learning in Education**

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## **Listening Matters**

I study learning by examining the role of listening in education. More specifically, I study how teachers and children listen and respond to one another and how that matters for making learning work. The study of listening is interdisciplinary and draws from philosophy, communication, education and other fields. Biesta (2006) calls on us to consider “how to live with others in a world of plurality and difference” (p. 1). It is through education that we learn to respond *responsively* and *responsibly* to one another as unique human beings, or not. I study listening in response to this call: Namely, if we are to learn to respond *responsively* and *responsibly* to others, we need to learn more about *if and how we listen to* one another in educational settings and beyond. In other words, if education, as an endeavor, is about learning to respond to the world around us, then listening becomes central to our abilities to respond responsively and responsibly. Listening matters because what we have the opportunity to hear, if and how we hear it, and whether or not we are heard influences our responses and capabilities to respond responsively and responsibly to others, and to learn. Because education is a means by which we learn to become human in particular social, cultural, and historical circumstances, then I study listening to know more about if and how listening matters as individuals participate *in* education.

## **Theoretical Framings**

I situate my work in socio-cultural theory: (1) learning is social and mediated (Vygotsky, 1986); (2) Lave and Wenger's (1991) learning as legitimate peripheral participation: If we understand learning as participation, then the question is not, “*If* learning occurs?” but rather, “*What* learning is occurring?” (3) Dreier's (2008) “theory of persons in social practice.” I draw these theories together to consider the role of listening in educational contexts. We listen in webs of interaction. When we listen, we hear, are heard, and respond to one another's participation in local contexts that are situated in structures of social practices. What we hear and how we are heard is informed by our ideas, beliefs, and sense making, as well as one another's identities and interactions within structures of social practices. Thus, in order to better understand if and how listening matters, it needs to be examined within these webs of interaction. This includes recognizing the structures of social practices that shape what is said and who is heard in particular interactions and how the listening in the interaction has an impact toward affirming or interrupting participants' identities, knowledge, beliefs, participation and the structures of social practice. Listening matters. It is one of our human capacities that implicates us as social beings in terms of what we have the opportunity to hear, how we are heard, and how we respond to another.

## **Methods**

To study the roles of listening in learning, I use qualitative methods drawn from ethnographic, interaction analysis and case study methodologies. To triangulate my data and analysis, I capture and analyze video of classroom interactions, interview participants to learn more about their experiences, invite them to be researchers with me and keep journals, and observe their participation in classrooms. I draw from these data to describe and analyze “listening” interactions and participation between teachers and students, between students and their peers, and between teachers, students and the content they are studying.

## **Next Steps and Aims**

My research agenda aims to speak to three areas. First, I aim to contribute to what we understand about listening inside teaching and learning. This work includes describing if and how what we hear and how we are heard matters for both teachers and students as they engage in education. Second, I aim to speak to the roles of listening in content areas. Currently I focus on listening during mathematical discussions and how hearing and being heard impacts children's opportunities to learn mathematics. Third, I aim to speak to the preparation and professional development of teachers' listening practices. My main questions focus on how teachers create classrooms and schools where children and teachers themselves are heard, and how that matters for children's opportunities to learn and participate in education. The study of listening has implications for understanding how humans learn and become through our listening practices, and why it matters when engaging in education.

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# Supporting Equitable Participation in Socially Relevant Science

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My research focuses on socially relevant science learning with an emphasis on climate change science. I use a sociocultural lens to examine how learners negotiate scientific, cultural, political and personal experiences, beliefs and epistemologies in the construction of scientific identities, use evidence and epistemological frameworks in argumentation practice, and participate in scientific practices using innovative data analysis and social media/networking technologies. Using ethnographic methods and a framework of learning as “life-long, life-wide, and life-deep”— occurring across a lifetime, across all life contexts, and mediated by cultural values (Banks et al, 2007)— I examine how engagement in diverse communities across contexts informs and can be leveraged to support participation in the scientific community and in everyday scientific decision-making.

Climate change is an important area of research due to its socially controversial context and deep societal implications. Troublingly, high poverty, under-resourced areas are projected to be the communities most impacted by climate change, and communities in these areas often have large populations of groups underrepresented in science (National Academy of Sciences, 2008). There is an inherent inequity in the impacts of climate change and the agency of communities to respond to changes. It is therefore imperative that climate change education intentionally attends to issues of equity and draws on learners’ lived experiences (Walsh & Tsurusaki, 2014). My work specifically focuses on: 1) Supporting underrepresented groups in socio-scientific decision-making, 2) Promoting interdisciplinary partnerships, and 3) Supporting participation in science through the development and use of innovative technologies, as described below.

In my dissertation work, I examined how a culturally responsive, student-driven approach that leverages students’ everyday experiences with climate change can deepen conceptual understandings and shift attitudes toward climate change for diverse learners, including those who initially disagree with the scientific consensus. Ongoing research uses a critical lens to reveal learners’ diverse experiences of science and place, to examine strategies for supporting navigation between participation in home, community and school contexts. I seek to foreground non-dominant narratives of climate changes through engagement in interdisciplinary learning at the intersection of science, society, art and English Language Arts. I work with youth, teachers, scientists, filmmakers, animators and theater professionals to design learning environments that bridge personal experiences and values with scientific knowledge and practices through storytelling and filmmaking.

In the second strand of my work, I study collaborations between educators, stakeholders, scientists, youth, communication professionals and others. I have studied the communication practices of climate scientists, and how scientists, educators and students interact in the teaching and learning of scientific practices. Here, scientific practice is understood as multi-dimensional, including conceptual, epistemic, social and technological dimensions (cf. NRC, 2009). In the teaching and learning of practices, different partner groups emphasized or de-emphasized dimensions in both intentional and unintended ways, due to their particular expertise and their positioning by others and by themselves. This suggests that while interdisciplinary partnerships between groups with varied expertise are valuable for supporting holistic learning of practices, these partnerships must be strategically structured to foster effective collaborations.

The above work is accomplished in part through the development and analysis of technologies. These include platforms that support professional development for teaching scientific practices, and those that connect home and school environments. Examples include a) development of a multi-modal Web 3.0 platform built on universal design for learning principles, that uses social media, video telestrations, tagging, and other tools for interactive community-based professional development and b) leveraging of home energy technologies (e.g. PG&E Smart Meters) to bridge students’ home and school science experiences as a mechanism for engagement in energy content, scientific analysis, argumentation and communication practice, and environmental actions.

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# Expressive Technologies for Middle School Math and Science

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## Motivation and Theoretical Underpinnings

My research explores how young people come to adopt computational tools, methods, and languages to express and test their own ideas about complex scientific and mathematical phenomena. To do so, I design computational toolkits that build on familiar forms of personal expression for young people—such as storytelling, sketching, or animation—to connect to the more formal tools and discourses used by STEM disciplinary communities. Below, I provide two specific examples of this work. These examples integrate common theoretical underpinnings: (a) resource-based perspectives toward thinking and learning (diSessa, 1993; Sherin et al., 2013), (b) Constructionist pedagogical principles (Papert, 1980), (c) attention to representational infrastructure and representational competence in student sensemaking (Kaput, 1998), and (d) learning as participation in discourse practices (Sfard, 2008). I use a design-based approach, with the goal of eliciting and studying new types of learning with and around these computationally-mediated learning environments (Cobb et al., 2003). I work primarily with grades 5–8 learners in interview, after-school, and classroom settings and use thematic coding and microgenetic methods to explore their development over time.

## SiMSAM: Bridging Student, Scientific, and Mathematical Models

Increasingly, computational simulations, visualizations, and data analytic methods are used to construct, test, and compare scientific theories. These tools can also make scientific phenomena more accessible to young learners. The SiMSAM project explores how students learn to use simulation and data analysis to express, test, and share their own scientific conjectures, and how to support them in doing so. My colleague Brian Gravel and I are designing a web-based modeling environment, SiMSAM, for students in grades 5–8. SiMSAM enables users to create (1) Stop-Action Movies using craft materials (e.g., construction paper, cotton balls, drawing, etc.); (2) Simulations using a visual interface that allows students to import images from their original animation and program them by demonstration, and (3) Measurement tools to analyze data generated by their simulation. The hypothesis that underlies the SiMSAM project is that by more tightly integrating students' drawings and animations of scientific processes with simulation by turning students' own objects into programmable entities, learners might more easily treat simulation as an extension of scientific expression.

## DataSketch: Supporting Computational Data Visualization in the Middle Grades

Technological advances are changing the way we collect, view, and interact with data. As a result, data visualizations move far beyond conventional graphs, tables, or diagrams to use problem-specific imagery and computational techniques to reveal patterns of interest. The DataSketch project explores the hypothesis that by exploring and constructing their own novel, interactive data visualizations, students can develop data literacy, learn important core disciplinary content, and engage in key STEM practices in powerful new ways. As part of this I am developing DataSketch: a tablet-based tool for students to create sketches and program them to respond to archival or live data input to become interactive visualizations. The project includes (1) research on grade 6–8 students' knowledge and development related to computational data visualization, and (2) continued development and study of DataSketch and related curricular and sociotechnical supports.

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## Acknowledgments

This is based on work supported by the National Science Foundation Grants IIS-1217100 and IIS-1350282, the Tufts University Mason Fund, and the Tufts Faculty Research Fund. Any opinions, findings, and conclusions or recommendations expressed in this work are those of the author and do not necessarily reflect the views of the NSF or Tufts University.

# **Doctoral Consortium**



# **Learning to Teach Elementary Students to Construct Evidence-Based Claims about Natural Phenomena**

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## **Goals**

This dissertation aims to contribute to the field's understanding of how pre-service teachers (called interns in this study) learn to support elementary students in constructing evidence-based claims in science, and how their teaching practices related to this goal change over the course of an elementary teacher education program. The overarching question I pose is: "How does a practice-based approach to teacher education help interns learn to teach in a way that integrates the scientific practice of constructing evidence-based claims with science content?" I use two analytic questions to frame this study: With regard to supporting elementary students to construct evidence-based claims of natural phenomena, (1) how do the interns' practice and corresponding knowledge change over time within a practice-based teacher education program? and (2) how do interns describe their learning over time?

## **Background**

Engaging in scientific practices integrated with content facilitates deeper learning of science (NRC, 2012). However, beginning elementary teachers face the challenge of teaching multiple subjects and need support in learning to engage students in disciplinary practices (e.g., constructing evidence-based claims in science) (Appleton, 2007). A practice-based approach to teacher education uses pedagogies of professional practice (e.g., decomposing and representing elements) (Grossman et al., 2009). This approach has shown potential in supporting secondary science teachers' learning (Thompson, et. al., 2013), yet little is known about its impact on pre-service elementary teachers' learning. My research will help fill this gap by extending the field's understanding of learning to teach science.

## **Study Overview**

To describe interns' learning of the teaching practice of supporting students to construct evidence-based claims, I will conduct a longitudinal qualitative study (Miles, Huberman, & Saldana, 2014) of a group of elementary interns learning together within a coherent, two-year, practice-based teacher education program. Drawing on a situated, sociocultural perspective of learning (Putnam & Borko, 2000), this methodology will enable me to describe learning over time within a particular context. This study will examine several cases by following closely a set of Focus Interns from the cohort. I will examine the interns' assignments from the program across a range of courses and field experiences as well as interviews with Focus Interns. During my analysis, I will draw on the literature base to develop coding schemes (e.g., Herrenkohl & Cornelius, 2013) and add emergent codes.

## **Preliminary Findings**

I will finish my data collection in May 2014. My preliminary analyses suggest changes in learning across time and variation among interns' abilities and knowledge to support students to construct evidence-based claims in science. For example, most interns were able to probe students' thinking for additional evidence or reasoning about their claims at the end of the first year. However, some struggled to ask questions that would help students to construct their evidence-based claims. This suggests variation in interns' practice and potential for learning.

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# **Attributions And Epistemology in Conversation: How Math Tutors and Students Co-Construct Accounts of Failure and Knowledge**

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Schools in underserved urban communities continue to struggle to stoke student interest in math. One factor responsible for math aversion is that young students, especially from minority and female populations, form problematic thoughts about failure (Shores & Smith, 2010). Maybe the most problematic among them is that students credit impediments in math to wholesale lack of ability. The resulting loss of motivation is warranted if communities consider ability to be both stable and beyond control, rooted in fixed or native intelligence. How can we move past inert models of ability and have conversations with young students that promote flexibility in assessing failure, and most importantly, that boost motivation and resilience in front of obstacles?

Educational researchers have studied students' reflections on success/failure within the framework of attribution theory. In my dissertation, I expand on attribution theory in two important ways. First, students most commonly assess failure in the course of school activities and within a community of peers, teachers, and parents, and yet the vast majority of attribution research occurs in post hoc interview and survey settings, framing attribution construction as individual mental effort (Weiner, 1983). To address this misalignment, I recruit interaction and conversation analysis methods to study the handling of attributions of success/failure in discourse and within an intact math-learning environment. What are the characteristics of attribution construction in social interaction? And how can we intervene to foster more productive attributions of struggle? Secondly, educators have long favored drawing attention to effort over ability, and though successful, the approach reinforces notions that ability is a fixed trait, blurring its boundary with skill. In contrast, I study how students can transform their thoughts about ability alongside effort. Educators know that math ability is not an on/off switch, where you either have it or you don't. Could students think about math difficulty as coming not from wholesale inability but from lack of one or more skills needed to create knowledge? Far from a genetic trait, ability derives from the capacity to recognize the situated complexity of activities (Goodwin, 2013)—with their numerous hooks and scaffolds—and to practice discipline and fearlessness in the search for ways to improve. If students thought about ability and knowledge in these terms, how would they assess failure?

To study these new angles, I have partnered with an elementary- and middle-grade, non-profit, STEM after school program to conduct a design research project. The after school program, located in an underserved urban community in Los Angeles and serving more than 70 students, offers daily homework tutoring and STEM enrichment projects, drawing on a cohort of volunteer tutors from local colleges and businesses. Because I have been involved with the program since its founding three years ago, this project is part action research and part design research, moving forward with the simultaneous goals of building learning theory and revising the teaching practices of the program. In the present study, I have recruited 10 students struggling in math and 10 tutors assigned by the program administrators to each student.

The research design begins with two weeks of baseline, video-recorded tutoring sessions (two dyads filmed each day). Over 16 weeks, the tutors and I will reflect on their teaching practices, examine the topic of failure, and implement a new pedagogical approach each week. In this way, the study presents a grounded analysis of the existing discourse practices and also tests the potential for variation in those practices after a series of motivated interventions, organized through a conjecture map (Sandoval, 2013). Even though I have entered the study with interventions in mind—focused on drawing attention to the situated resources needed for knowledge and to the division of labor in assessing failure—the goal is to recursively design the interventions each week based on feedback from the tutors/students and based on the conceptual frameworks of attribution theory and epistemic cognition. Analytically, I draw on conversation and interaction analysis tools to throw light on the moment-to-moment organization of the dyads' reflections on failure and choices of next actions. The analysis will depart from existing CA research on causal reasoning in storytelling and from IA research on multi-modal features of settings such as hand gesture and material resources known to shape interaction. As I am currently in my first weeks of data collection, I hesitate to make strong claims about preliminary findings.

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# **Identity and Collaborative Learning: Examining the Microdynamics of Social Positioning in Mathematical Group Work**

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## **Goals of the Research**

In mathematics education, learning is documented as racialized and gendered. Research investigating how social identity (i.e., social categories such as race and/or gender) affects student learning is growing, but remains a pressing topic. This research is particularly important within the context of group work wherein students from various social groups are encouraged to collaborate. During intergroup interactions, perceived status differences across groups can give rise to power dynamics which can shape the way students position one another and lead to differential access to learning opportunities (e.g., Langer-Osuna, 2011). Given the trending reform movements in mathematics education that endorse meaning-making through collaborative learning, there is a push to understand not only the sociohistorical systems of power that underlie these collaborative learning contexts, but also how this power is constructed through moment-to-moment interactions between students.

The goal of this work is to investigate how social identity is involved in the collaborative learning experiences of students from non-dominant social groups. By engaging in a microanalysis of student interactions, this research also investigates the microdynamics of positioning and how it influences collaborative learning. Adopting an interdisciplinary framework that draws from the learning sciences and social psychology, this work seeks to provide a more nuanced understanding of the role of social identity in collaborative learning.

## **Background of the Project**

This research is grounded in sociocultural theories of learning and identity. It stems from the idea that identity is a fluid social construct that emerges through interpersonal interactions and that learning involves shifts in identity and the notion of ‘becoming’ (Nasir, 2002). To account for the ways that identity develops through moment-to-moment interpersonal interactions, I draw on the notion of *positional identity* (Holland, Lachiotte, Skinner, & Cain, 2001). Within collaborative learning activities, students position one another in ways that afford differential access to spaces, conversations, and participation in a practice (e.g., Leander, 2002). Research is beginning to reveal the ways in which positioning is tied to social identity and how, for example, students from dominant racial and gender groups have greater access to learning opportunities within collaborative group work. The goals of this research are to extend this body of research and, additionally, to consider how race and gender intersect to shape collaborative learning experiences.

## **Methodology**

This study examines the collaborative group work experiences of six focal students (i.e., students from non-dominant social groups) enrolled in secondary school mathematics courses in a large Canadian city. The focal students were videotaped as they engaged in group work and, using the video recording as a prompt, were subsequently interviewed about their experiences using stimulated recall techniques. Focal students also participated in final interviews that explicitly asked about the role of social identity in collaborative group work. All interviews were semi-structured in nature. To facilitate a microanalysis of the video, I will use StudioCode video analysis software. The interviews will undergo descriptive and thematic passes of coding and themes will emerge from constant comparison between the data and the gradual elaboration of open codes.

## **Current Status**

I am in the early stages of data analysis. Preliminary analysis illustrates the verbal and non-verbal forms of positioning that shaped the learning experiences of focal students as well as the tendency for these students to discuss the role of friendships in group work and to refrain from explicitly talking about race and/or gender.

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# Towards a Theoretical Model of Immersion in Inquiry-Based Science Learning

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## Goals and Background

Immersive learning environments have been assumed to support students' learning by providing engaging experiences (Dede, 2009). Despite such assertions, the construct of immersion is ill-defined in relation to learning, while existing theoretical models of immersion have usually been developed for non-educational immersive environments, such as commercial games (e.g. Brown & Cairns, 2004). In an effort to address this research gap, Scoresby and Shelton (2011) focused on university students employing immersive educational games for poetry and proposed an educational model of immersion. Their model conceptualized immersion as a linear process towards the achievement of flow and presence and was composed of four succeeding stages: students' interest, emotion, motivation and engagement. However, the model provides limited insights on how immersion is intertwined with the learning process or the factors contributing to the achievement of the four succeeding stages. In addition, while the model reflects students' immersion in game-based virtual worlds for poetry, there are no warrants that this model could conceptualize students' immersion in inquiry-based environments for science education. Using Scoresby and Shelton's model (2011) as a starting point, the present doctoral dissertation focuses on conceptualizing secondary school students' immersion in the context of inquiry-based science learning (IBSE), in an effort to unpack the construct of immersion in technology-mediated IBSE and explore its relation to learning.

## Methodology

This doctoral study adopts a design-based research approach aiming to develop a theoretical model explaining immersion in inquiry-based learning environment for learning in science. The first research phase includes two cycles of design and implementation of the "Trace Readers", an augmented reality (AR) inquiry-based learning environment for high-school students. During this research phase, each cycle will be realized as a multiple-case study focusing on 10 pairs of high school students. Empirical data will be collected through (a) recordings of students' discourse and actions during the learning sessions, (b) pre-post conceptual understanding tests and (c) post-session individual interviews, focusing on the experiences of immersion. The data collected from each case study will be analyzed qualitatively in an effort to inform and to revise the theoretical model of Scoresby and Shelton (2011) as well as to improve the immersive learning environment from cycle to cycle. The second research phase will include a comparative case study between two groups composed of 10 pairs of high-school students each. Each group will use the "Trace Readers" learning environment using two forms of technological mediation: in the form of a desktop, online learning environment or in the form of an AR application. Similar data collection and analysis procedures will be adopted; the contrast between the two groups is expected to contribute to the enhancement of the theoretical model of immersion for learning as we anticipate that the two technologies will have a different impact on students' immersion.

## Current Status

I spent the past year conducting literature review on immersive learning environments and designing the first version of the "Trace Readers", an educational augmented reality application. This application was piloted last summer with 9 pairs of high school students. Preliminary analyses indicated that immersion was affected by several factors related to the user interface, the narrative, the learning space or other unforeseen distraction. At the same time, immersion seemed to be a graded experience that varied between students' pairs and led to the differentiation of students' inquiry-based activity and the learning performance of each pair. My next steps will focus on the re-design of the "Trace Readers" and on its implementation, in light of the data collected during the pilot study.

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# **Co-Constructing Opportunities for Inquiry: A Cross-Context and Development Ethnography of Young Children's Inquiry**

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## **Goals of the Research**

My research explores naturally occurring inquiry practices of young children across contexts and over time. I hope to enrich our understanding of moments when children engage in inquiry in their everyday lives, and by doing so over time contribute to our understanding of the development of children's inquiry practices. I also seek to explore children's learning as they move across multiple contexts, a fundamental yet understudied phenomenon (Leander, Philips, & Taylor, 2010). Through this work I hope to provide theoretical and methodological tools for those designing learning environments to better support STEM learning across contexts throughout young children's lives.

## **Background of the Project**

The Early Learning Across Contexts (ELAC) project is funded by a NSF Science of Learning Center grant to the LIFE Center (Learning in Informal and Formal Environments) and is led by Reed Stevens. ELAC consists of two phases of video-recorded observations of focal children in home and school contexts: the preschool phase, ages two to four; and early elementary phase, ages six to eight. Four children participated in both phases. In addition to video-recorded observations, the early elementary phase includes interviews with participants and their families, interviews with teachers, and video collected by the focal participants.

## **Methodology**

I follow the Interactional Analysis tradition (see Goodwin & Heritage, 1990) to identify patterns in interaction based on participants' talk, gaze, gesture, and other modalities used to coordinate joint activity. Drawing on Tuomi-Gröhn's (2003) definition of practices as patterns in interaction, I identify local family practices for inquiry by examining patterns in how children coordinate attention and engage in exploration of a phenomenon of interest with others. I also identify Characteristic Adjacency Pairs (CAPs)—a form of adjacency pair (Schegloff, 1972) central to participants' inquiry practices—identifying their occurrence across contexts to explore the interactional arrangements that support and constrain opportunities for everyday inquiry. By drawing on the early elementary data interviews and the video collected by participants of their own activity, I am able to position this analysis in relation to the language that participants themselves use to describe their activity.

## **Preliminary Results and Status of the Project**

I have examined video data of one participant, Marie, from both ELAC phases and identified a practice of inquiry in which she engaged frequently with her family. In prior work I've performed a comparative analysis of the arrangement of people and activity during all moments in which Marie employed a first turn of one Characteristic Adjacency Pair while in school (i.e., when she attempted to engage someone in her family inquiry practice). This allowed me to explore why Marie's attempts to engage in her family inquiry practice in preschool were not successful (in that she did not receive the response she was demonstrably seeking). In recent analyses I've explored Marie's family practice of inquiry across both ELAC phases to map the constellation of features of this family's practice of joint inquiry. Currently I am extending this process of analysis to other focal participants.

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# **Learning to Notice: Supporting Students' Meaningful Engagement in Scientific Practices**

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The Next Generation Science Standards present an ambitious vision for students' meaningful use of scientific practices to develop and evaluate explanatory models of phenomena. Meaningful practice, rather than rote activity, requires that students understand what they are doing, how it will help them to achieve their goal of explaining the phenomenon, and what counts as success. However, meaningful use of scientific practices in classrooms is uncommon and the steps needed to realize these shifts in classroom practice have not been well articulated (Windschitl et al., 2012). With states adopting NGSS in increasing numbers, more work is needed to cohesively study teachers' attempts to 1) interpret and implement these new instructional practices in their classrooms and 2) understand the impact of teacher learning and shifts in teacher practice on students' meaningful use of scientific practices. To address these goals, I conducted two studies during the 2011-12 and 2012-13 school years.

## **Study 1: Examining the Epistemologies Guiding Meaningful Engagement in Scientific Practices**

Study 1 explores what *meaningful engagement in scientific practices* looks like in classrooms. As students engage in the modeling practice, they develop and use epistemic considerations that guide and help them make sense of their scientific work (e.g. Sandoval, 2005). Berland et al. (in progress) refer to these considerations as *epistemologies in practice* (EiPs) and identify four dimensions of these EiPs that appear helpful when students explain phenomena: *mechanism, justification, audience, and generality*. Two questions framed this study: "What epistemologies do students consider as they develop and evaluate explanatory models?" and "How do these epistemologies guide their engagement in modeling?" I videotaped four multi-day lessons during which sixth graders used diagrammatic, expressed models to explain how and why they could detect an odor source from a distance. I coded the classroom discourse to assess differences in how the dimensions of students' EiPs may be implicitly or explicitly guiding their scientific work. Preliminary findings indicate classroom differences in 1) the students' relative attention to the justification and generality dimensions while engaged in persuasion and 2) their role in the knowledge building. One potential explanation could be differences in teachers and students' perceived purpose for evaluating models (Berland & Hammer, 2012).

## **Study 2: Learning to Notice Meaningful Aspects of Students' Engagement in Scientific Practices**

Study 1 identified three important aspects of students' engagement in modeling: 1) the epistemologies guiding students' work, 2) students' level of participation in the knowledge building, and 3) the degree to which students' intuitive ideas and developing explanations inform classroom decisions. Using this conceptual framework, I designed an intervention over a six-month period to help Kami, one of the teachers from Study 1, help her students use scientific practices in more meaningful ways. Two questions framed this design study: "To what extent does Kami develop the ability to notice these aspects of meaningful engagement in scientific practices?" and "In what ways does this noticing lead to changes in her teaching practice and students' use and understanding of scientific practices?" I conducted regular *cogenerative dialogues* (Tobin, 2006) with Kami and her students to reflect on the classroom enactments and co-develop interventions to make the students' learning more meaningful. This study examines how attention to these dimensions of meaningful practice can impact teacher practice, students' use of scientific practices, and students' understanding of the scientific endeavor. Evidence for these shifts come classroom video, teacher and student interviews, and surveys.

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# **Collaborative Learning: An Effective Component of Productive Failure?**

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## **Goals of the Research**

Learning approaches, which allow students to collaboratively solve problems prior to receiving instructions, have been proven effective for developing conceptual knowledge (e.g., Productive Failure, PF, Kapur, 2012). However, so far the role of the collaboration within PF is not clear (Collins, 2012). Therefore, we aim at investigating the role of collaboration as described below. As a second step, we target at examining whether the beneficial effects of PF can be further promoted by adding a third and a fourth phase for practice and reflection after the two regular phases: problem-solving followed by instruction. Also for these additional phases, our goal is to shed light on the effects of collaborative as compared to individual learning.

## **Background of the Project**

Against the literature on the benefits of collaborative learning, we assume that collaboration has positive effects on conceptual knowledge acquisition. For instance, as students interact in a collaborative learning setting they are enabled to discuss and verbalize their ideas and consequently elaborative processes are initiated (e.g., Slavin, 1996). Additionally, Chi's ICAP framework (2009) predicts a superiority of interactive (e.g. build on partner's contributions during collaborative problem-solving) and constructive (e.g. generate ideas that go beyond the presented information during individual problem-solving) activities over active learning activities (e.g. repeat the presented information). This supports the hypothesis that solving a problem collaboratively within PF has a larger effect on the acquisition of conceptual knowledge than solving the same problem individually.

## **Methodology**

In order to test our hypothesis we conducted a quasi-experimental study ( $N= 55$ ): In two PF-conditions students first solved a problem and then received instructions. During problem-solving students worked pairwise (PF-Coop) or individually (PF-Ind) on the problem. In a third condition (DI) students first received instructions and then solved a problem collaboratively. All collaboratively working students were videotaped.

## **Current Status and Preliminary Results**

Our study replicates the beneficial effect of PF as compared to DI: Students in both PF-conditions gained significantly more conceptual knowledge than students in the DI-condition ( $F [1,48] = 4.6, p = .03$ ). However, our two PF-conditions did not differ significantly with regard to the conceptual posttest ( $F [1,48] = 0.4, p = .84$ ). Due to the high variance within the PF-Coop-condition (PF-Coop:  $M = 7.88, SD = 5.43$ ; PF-Ind:  $M = 7.71, SD = 3.29$ ; DI:  $M = 5.26, SD = 3.91$ ) we assume that the quality of collaboration moderates the effect on conceptual knowledge. We are currently conducting intensive video analyses of the videotaped collaboration data to test this assumption. In addition, we plan to conduct a follow-up study with a full  $2 \times 2$  design in order to separate the effects of timing of instructions and social form.

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## **Acknowledgements**

The research leading to these results has partly received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 318051 - iTalk2Learn project. This publication reflects only the author's views and Union is not liable for any use that may be made of the information contained therein.

# Drawing and Dissection: Improving Understanding in Anatomy

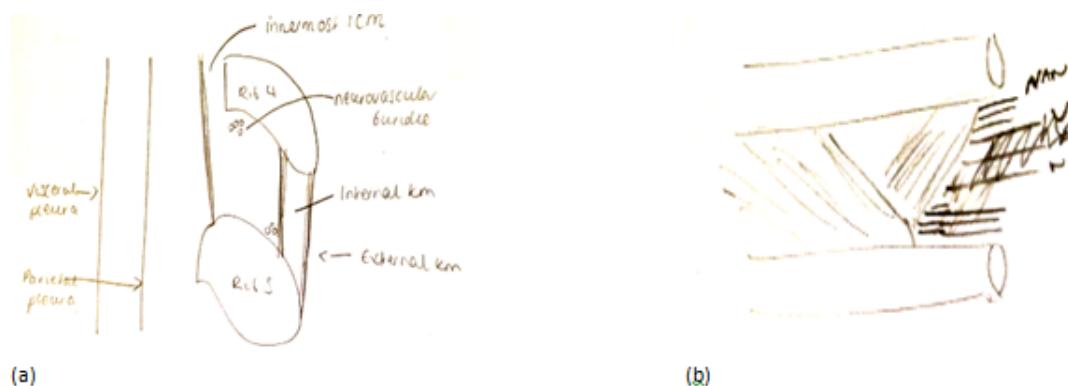
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## Summary of Research

Anatomy has utilised visual representations for hundreds of years, using visual representations of both internal and external parts of the body. For example, the artist's Leonardo Da Vinci work was strongly informed by his interest about anatomy (Bay & Bay, 2010). The basis of Leonardo's drawings in anatomy was to display the structure and sometimes the function in respect with the dissected material (Jose, 2001). Through all of these ages, a comprehensive understanding of anatomy is highly important in medical science. Anatomy is strongly related to spatial concepts as the shape of structures, the way that they are relative to each other and how they are connected. Medical practitioners carry out procedures that depend on their mental spatial representations of the structures that are internal and not direct visible (Hegarty et al. 2007).

Medical students at the University of Nottingham are taught modules in anatomy in their first two years of study. These involve weekly dissection sessions, in which students can use visual representations. My research is exploring whether the systematic inclusion of drawing activities carried during briefings can improve both student learning and lecturers' assessment of student understanding. I focus on drawing for a number of reasons basing my arguments primarily on those from science education (e.g. Ainsworth, Prain and Tytler, 2011) including the need for students to be encouraged to develop the representational practices in their field, that drawing can support reasoning if students align their drawing with observation or their emerging understanding and lastly, supports assessment when students make their thinking visible.

My research is conducted within an on-going curriculum and I am using a mixed methods approach to answer my questions. This has involved an initial exploratory phase based on observation of existing practices, semi-structured interviews with lecturers and students about representational practices and has evolved to quasi-experiments to explore drawing as preparation for or reflection on dissection.



**Figure 1.** Example of drawing activity from two students' workbooks: *Make a drawing of a vertical section through a typical intercostal space. Label the contents and layers.*

So far, my research has involved analysis of prompted and spontaneous drawing activities in student workbooks (Figure 1) and these students have been interviewed concerning their drawing practices, to explore why students draw, what influenced their choice to draw specific representations and what problems they experienced when drawing in anatomy. Lecturer interviews and observations conducted and focus on their use of visual representations including drawing in their teaching practices. I have just started an experimental comparison of groups of students drawing pre and post whole-body dissection to explore the use of drawing to assess changes in understanding of anatomy as a consequence of dissection activities.

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## Acknowledgments

This research is funded by the Higher Education Academy UK, as part of the Mike Baker Doctoral Programme.

# **Have I Become What I Once Beheld? Identity Construction of the Other in Virtual Worlds**

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## **Introduction**

In an effort to present young people the opportunity to radically extend their identities, this study explores the construction of an identity not only unfamiliar to its participants, but also devalued by society. Virtual Worlds (VW) are persistent three-dimensional massively multi-user social environments in which avatars are employed to represent residents (Peachey, Gillen, Livingstone, & Smith-Robbins, 2010). The affordances of a VW were harnessed to facilitate the experience of being marginalized, disempowered and devalued and to encourage reflection on life as presently lived within socially-prescribed boundaries. The objectives are (i) to explore how adolescents enacted identifications in relation to the Other, (ii) to investigate whether and how role-playing in *Second Life* facilitated identification with the Other.

## **Methodology**

The data, collected between March 2013 and June 2013, were from three groups of five able-bodied 17-year old students studying in a post-secondary institution. A multifaceted curricular intervention was implemented to facilitate perspective-taking on disability issues. The first analytical approach employed theoretical concepts as the basis for constructing a framework representing participants' discourse moves (Rappa, 2013). The second analytical approach involved mapping the full range of participants' discourse positions.

## **Preliminary Findings**

Goffman (1981, p. 128) describes footing as “[p]articipants' alignment, or set, or stance, or posture, or projected self” that involve code switching or changes in pitch, volume, rhythm, stress, tonal quality. This notion of footing has been extended to include discourse moves as reflected in Table 1. These moves illustrate how able-bodied adolescents rendered the discourse of persons with disabilities, showing changes in footing in relation to the case studies they had read prior to their role-play. The moves were mapped along an imitating-recasting continuum of being the Other and being one's possible self.

Table 1: Participants' discourse moves along an imitating-recasting continuum.

Imitating (Other) .....	Recasting (Self)	
Circumscribing	Extending	Inverting
Echoing	Reconstituting	

Clarke's (2005) positional mapping was also used to distinguish the identity sequence enacted by each participant who took on an avatar with a disability. These identity sequences illustrate wide-ranging responses to the experience of discrimination reflective of Goffman's (1963) seminal work on identity management.

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## **Acknowledgments**

The study reported in this paper is funded by a research grant, SUG30/12 NAR, from the Office of Education Research, National Institute of Education, Nanyang Technological University, Singapore. I wish to thank Dr. Julia Davies and all teachers and students who were involved in this study.

# The Role of Evidence and Models in Science Education

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**Abstract:** Students using evidence and explanatory models has recently been embraced by the Next Generation Science Standards. Study one investigates how students utilize bodies of evidence (simultaneous consideration of several pieces of evidence), rather than individual pieces of evidence, to understand competing scientific models regarding genetically based HIV resistance. Study two examines how middle school students construct models of inheritance based on complex evidence sets composed of multiple pedigrees. Study three explores how learning from the testimony of others, as a source of evidence, influences how students view evidence in terms of its quality and relation to explanatory models.

## Study 1

Prior research on modeling in science classrooms typically examines how students assess individual pieces of evidence. This study examines how middle school life science students reason about bodies of evidence (simultaneous consideration of several pieces of evidence). The aim of this research is to advance understanding of student reasoning about bodies of evidence and scientific modeling. More than three hundred students, with four teachers, took part in this classroom based study. Students assessed four pieces of evidence related to competing models of HIV resistance in humans. Preliminary results suggest that many sophisticated reasoning strategies used by students involve inter-evidence corroboration as a key component of their assessment of the models.

## Study 2

Scientific modeling can be difficult for students because explanatory models often involve one or more key mechanisms that are difficult, or impossible, to observe during the course of science instruction in the typical classroom. This study was conducted with the same population as study one. We designed a four day lesson where students use complex sets of evidence in the form of multiple pedigrees to construct an explanatory model of the rules of inheritance. This lesson appeared near the beginning of the genetics unit and as such students had very little prior experience with the topic. Model construction and revision, when coupled with simultaneous evidence coordination, is a cognitively demanding task. We found that significant numbers of students were successful at developing models that are consistent with the available evidence, models that are internally consistent (do not contain self-contradictory elements) and could provide a scientifically normative account of Mendelian genetics.

## Study 3

Consider how we come to know the following pieces of information: Jupiter orbits the sun, and a hydrogen atom has a single proton. A vanishingly small minority of humans are in possession of painstaking empirical evidence that they have gathered themselves that can attest to these facts. Recent empirical research with students learning about climate change has shown that students who were willing to place their trust in the testimony of experts did better on comprehension tasks related to coordinating multiple documents that contain conflicting scientific information than did students who held the belief that knowledge is personally constructed (Strømsø, Bråten, and Samuelstuen, 2008). This research highlights a distinction, made by Elby and Hammer (2001), that trusting authority versus trusting one's personal construction of knowledge is not a matter of one being *per se* superior but rather it is more important, from a situated perspective, to look at what is most productive for learning in that particular context or domain. My interest in how students learn from the testimony of others should not be taken as an endorsement of transmissionist models of pedagogy that students should uncritically accept what they are told. Rather, I am interested in students using testimony to construct their knowledge in the way that scientists actually do. In this study we will examine how students evaluate different features of testimonial evidence while considering the claims and models of testifiers with varying expertise.

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# **Exploring Culturally Responsive Computing Education: Learning with Electronic Textiles in an American Indian Community School**

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## **Research Summary**

While research in the Learning Sciences has been concerned with teaching and learning as cultural processes (Nasir, Roseberry, Warren, & Lee, 2006), scholars have only recently begun to consider culturally-responsive computing education (Eglash, Gilbert, & Foster, 2013). With few exceptions (Eglash, 2007), American Indians have been absent from this body of work in spite of the fact that American Indians fair poorly in U.S. educational systems (Grigg, Moran, & Kuang, 2010) and are especially underrepresented in STEM fields (Zweben & Bizot, 2013). My dissertation research seeks to address these issues by examining how culturally responsive approaches to computing can provide more design agency to American Indian students learning about computation with electronic textiles.

Electronic textiles (e-textiles, hereafter) are a relatively new form of tangible, programmable media in which users stitch circuits using conductive thread, a sewable microcontroller, and a variety of sensors and actuators (Buechley, Peppler, Eisenberg, & Kafai, 2013). These so-called “soft circuits” are incorporated into clothing, home furnishings, and soft toys to create interactive artifacts. Because e-textiles are hybrid in nature, combining craft practices that are common in many indigenous communities (e.g. sewing, decorative beading) with circuitry and computing concepts, they provide a unique opportunity to integrate cultural practices into learning about computation. Working with 36 junior high school students in a Native Studies class at an American Indian community school located outside of Phoenix, Arizona, I designed and implemented a three-week unit that connected Indigenous Knowledge Systems to computation through the making of e-textiles artifacts. I employed a culturally responsive open design model, where students were given fewer design constraints than when working with culturally situated design tools (Eglash, 2007) and examined how this impacted design agency, students’ ability to translate their ideas and identities into a technical realization. During the e-textile unit, I took daily field notes, documented students’ progress with photographs, and video recorded class sessions when students were amenable. I then conducted reflective interviews with students at the conclusion of the unit.

Preliminary data analysis highlights the importance of community context, student perspectives on computing, and the importance of providing design constraints within culturally responsive open design models.

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# **Play Your Way Into Math: Supporting Prevocational Students in a Computer Game-based Learning Environment**

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## **Project Goal**

The overall research focus in this project concerns the affordances of computer game-based learning (CGBL) for prevocational students, in the domain of mathematics. The effects of different forms of elicited reflection on both students' acquired knowledge and motivation during game-play are examined. The goal is to identify concrete conditions under which CGBL establishes positive learning effects.

## **Theoretical Background**

Overall, expectations of CGBL for education are high. Games have the potential to influence learning in two ways; First, games have *motivational* properties that are likely to generate more motivated and engaged learners, what results in higher time on task and better learning. Second, games influence the *cognitive learning processes*. Meaning that in games learners learn through manipulation and observation, which generates an intuitive way of learning (de Jong, 2006). A side-effect of this intuitive learning is that the acquired knowledge is implicit (students learn to solve a problem, but remain unaware of the underlying processes and their effects). As a result, even though students learn from CGBL, transfer of knowledge to other contexts (e.g. domain knowledge tests, real-life situations) often fails. Support can optimize knowledge acquisition from CGBL environments (ter Vrugte & de Jong, 2012). Reflection is an essential element of the learning process and is known to support the development of meaningful understanding. However, it is not a standard element of educational games. Adding support that elicits reflection is likely to foster students' development of more explicit knowledge.

## **Methodology and Design**

To conduct the research a CGBL environment was designed. Within this environment the students take on a role as hotel employee. During their virtual career the students encounter problems and fulfill tasks that help them to understand, practice, and master the math domain of proportional reasoning. In a series of studies the effects of different forms of reflection on students' acquired knowledge and motivation will be investigated. Data-collection encompasses: domain knowledge tests, motivational measures, ability measures, and logfile recordings.

The first study utilized a 2x2 design to examine the effects of elicited reflection with or without specific information. As the students showed the tendency to explain material to each other, and explanation in collaborative settings is known to aid knowledge acquisition (Gijlers, Saab, van Joolingen, de Jong, & van Hout-Wolters, 2009), collaboration was opted as alternative approach to induce reflection. Hence, a second study used a 2x2 design to examine the effects of collaboration and competition. Subsequently, an exploratory study addressed the effects of a combination of collaboration and in-game reflection prompts.

## **Results**

Results of both studies indicate that the educational game improves prevocational students' performance on proportional reasoning assignments. However, the in-game reflection prompts did not yield positive effects on knowledge acquisition or gameplay. Even when guided through the reflection process, reflection did not come natural to these students, and even when the students reflected, this did not lead to deeper understanding of the material. The data-collection of the second and exploratory study has recently been completed and results are expected to be presented at the ICLS 2014.

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# **Outside the Margins: Examining the Identities, Communities, and Contexts of Youth Who Attend Alternative Schools**

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## **Goals of the Research**

My dissertation is a qualitative study of high school age youth attending urban alternative high schools and will explore the following questions: What are the identities of youth attending alternative school and how are they in contrast to their identities in their previous schools? What in and out-of-school resources are available for youth to identify as learners and school community members and how are these resources taken up? How are these youths' out-of-school lives incorporated into their in-school identities?

## **Background of the Project**

One of the current interventions to stemming the tide of high school dropouts is the array of public alternative schools. While often labeled as 'at-risk' or 'potential dropouts', many students attending alternative schools thrive under the different academic, philosophic, and social structures of alternative schools. As in all settings, academic achievement in alternative schools is deeply connected with the identities that the alternative school students develop. This study looks at the identities of students entering into alternative schools.

I have chosen to look at the ways in which youth who have previously disengaged from school re-engage in alternative schools, creating their own paths of achievement. I hope to examine how the students describe who they were in their previous schools, how they see themselves currently in the alternative schools, and how they actually participate in and out of school. I plan to explore both the identities the youth describe and their identities enacted in practice. I also plan to look at the resources and opportunities the youth have to help them build their identities as learners and as members of the school community.

There is a wide breadth of schools labeled 'alternative'. In this study I will focus on alternative schools that take a 'Learning Choice' (Raywid, 1999) perspective over a 'Remedial Focus' (Raywid, 1990, 1994). These schools are often labeled innovative schools (Raywid, 1990, 1994) with either a) a belief that some students need different learning environments or b) that mainstream education is flawed and that unsuccessful students are unsuccessful largely because of the structures of mainstream schools.

## **Methodology**

This study is an ethnographic longitudinal study in two alternative high schools. In each high school, two to four case study youth will be observed and interviewed in multiple classes and two to three contexts outside of school. While surveys will be used to inform case study participant selection and documents will be reviewed to understand contexts, ethnographic interviews and observations will be the primary form of data collected. I will interview case study participants multiple times throughout the study and will also interview additional participants in each of the observed contexts.

For my analysis of both interviews and observations, I am interested in identifying discourse events as meditational tools (Wells, 2002) in which positioning, defining, and negotiating identities are prominent, where the participants signify or shift their membership in a community or across multiple communities, and engage in specific ways in community practices. In order to consider both power and the ways in which language is constructed in particular locations, I plan to analyze the identified discourse events using both Critical Discourse Analysis (CDA) and Systemic Functional Linguistics (SFL).

## **Current Status**

This study has been approved by the dissertation committee and the university human subject review board. Data collection for this study will be conducted between spring of 2014 and winter 2015.

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# **Design-Based Learning in a Community-Based Youth Program: Affordances for Youth Learning and Development**

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## **Goals of the Research**

The purpose of this multiple-case study is to describe the co-construction of design-based learning (DBL) environments by participants (youth and adults) in a community-based youth program (CBYP). Building on previous research (e.g., Kolodner et al., 2003; Roth, 1996) and grounded in a sociocultural perspective of learning, this study will explain variation in DBL-environments, by identifying and attending to salient features, including: (1) types of activities (including materials and tools); (2) adult volunteer facilitation strategies; (3) youth experiences and interactions with each other, adults, and artifacts; and the (4) institutional setting/history and other structural features. The features of a DBL-environment (and their affordances and constraints) will be related to opportunities for youth to: (a) participate in and learn through design; (b) express personal creativity; and (c) develop interest, attitudes, and overall psychological well-being. More broadly, this study will help address: (i) a need for volunteer educator-focused research; (ii) a need to study the processes in an activity setting that influence youth learning and development (e.g., Bevan & Michalchik, 2013).

## **Background**

There is a well-recognized need for learning environments supportive of open-ended problem solving and conducive to intrinsic motivation (e.g., Barron et al., 1998). Out-of-school time (OST) has been advanced as a space for youth development (Lerner et al., 2010) that is effective in nurturing youth interest, attitudes, and learning of science (Bevan & Michalchik, 2013). Concurrently, scholars have begun to recognize the potential of project-based learning and DBL (a pedagogical approach that emphasizes planning, designing, and making shareable artifacts) as an approach to foster problem solving abilities, creativity, metacognitive skills (Barron et al., 1998; Kolodner et al., 2003; Roth, 1996).

While there is a growing research-base on DBL in out-of-school time (OST), it has primarily originated from the informal science education community and the “Maker” movement. CBYP’s are another important activity setting in the OST space that reach millions of young people. CBYP programs are often organized by adult volunteers, offering youth voluntary participation and choice, and engage youth over an extended period of time. Programs are often facilitated by adults who may not have competence and confidence in pedagogical and/or youth development practices but who must ensure that activities are fun and motivating for youth who self-select into these activities. Given the voluntary nature of CBYP’s, youth interests, desires, and expectations must be considered, hence the focus on the co-construction of a DBL-environment by adults and youth.

## **Methodology**

Following theoretical lines influenced by constructionism, sociocultural perspectives, and positive youth development, and grounded in a social constructivist philosophy, this study employs naturalist multiple-case study methodology relying on qualitative data collection including observations, interviews, and focus groups. The research context is “Junk Drawer Robotics” for youth ages 9-13 in the 4-H Youth Development Program during OST which relies on volunteer educators. 4-H offers an interesting glimpse at historical influences as 4-H is rooted in a 110-year history fraught with tradition and a public image as “cows and cooking.”

## **Current Status**

Formative data (7 interviews, 6 observations) of two sites were collected in spring 2013 to inform prospectus development. From January through June 2014, data will be collected on one case. In summer 2014 this data will be analyzed to develop a guiding framework. Three additional cases will be followed next year.

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# Children's Use of Inscriptions in Argumentation About Socioscientific Issues

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Science educators have long assumed that school science helps children come to informed judgment outside of school, but we have little evidence this happens (Feinstein, 2011). A major reason is that while school science teaches people "what is true," engaging with science in everyday life often means deciding "what to do" (Nielsen, 2012). To complicate matters, socioscientific issues (SSI) that we encounter in daily life involve both scientific and non-scientific claims. What do children think counts as evidence for these claims? My study directly tackles this problem and, in particular, focuses on children's use of inscriptions because when we make science-related decisions in everyday life, we face inscriptions, such as diagrams and photos, often simultaneously. Understanding children's perceiving functional roles of inscriptions as evidence thus sheds needed light on how to connect school science with everyday practices.

Two intact combined 5th/6th-grade classrooms in a public university laboratory school were recruited, involving 3 teachers (2 in one class and 1 in another) and 106 students, who were in an ongoing program that helped the teachers develop instructional routines of coordinating claims and evidence across subjects. On a biweekly basis, the teachers and researchers met to identify opportunities for argument and persuasion, discuss ways of organizing learning activities and teaching strategies that afford productive argumentation.

I used a written test to measure students' performance at the beginning and the end of the fall semester. Students individually read a single-paragraph scenario of a socioscientific issue, made a personal decision, and wrote an argument to support it. Each scenario includes 8 inscriptions: 4 are scientific and 4 are editorial. I administered the pre-test early in the school year, and the post-test following the first semester. Presentation of tasks was counter-balanced to mitigate order effects. Between the two tests, science lessons specifically geared towards coordinating claims and evidence were videotaped, which yielded approximately 90 hours of videos.

Analysis on the tasks includes three aspects. First, frequencies of inscriptions students cite and ratios of scientific vs. editorial inscriptions illustrate what forms of evidence students tend to use. Second, coding and scoring on how students refer to a particular inscription (e.g. simply pointing, describing, interpreting) tell us about to what extent they see an inscription as evident and relevant to the claim they make. The third aspect is the functional role of inscriptions in relation to content. An appropriate use of inscriptions requires an explicit correspondence between contents and functions: using scientific inscriptions to provide data, and using editorial inscriptions to elicit emotions or values. The ratio of appropriate use of inscriptions for each participant thus indicates whether students understand different roles of inscriptions in an argument. Pre-post chi-squared tests (for aggregate data) or sign tests (for individual data) on measures in these aspects then examine whether there is any significant change between the two tests.

Another strand of analysis focuses on classroom interactions documented in the videos. First, I code teachers' discursive practices that potentially promote argumentation. For example, "who has a different idea?" is coded as *press for consensus*, "so how would you prove to him that you're right?" as *press for persuasion*, and "so you're saying that government websites are more reliable?" as *revoicing epistemic criteria*. I will also identify instances in which argumentation is the focus of class and code features of interaction that are potentially associated with changes in students' ways of arguing and using inscriptions. Field notes and video logs will also be used as sources of cross-reference for checking the typicality of the instances. Finally, charts of code frequencies across time will be created, displaying how teachers' and students' talks vary throughout the semester, which will help me analyze the interaction between instruction and students' argumentative behaviors.

I have administered and conducted content analyses on the pre-test as planned. As a group, students were more likely to use editorial inscriptions than scientific ones, suggesting an orientation to the issues that is more social. Also, they were more likely to merely "point" to particular inscriptions without saying why, which lends support to extant findings that children see data as self-evident, with no need for explicit description or interpretation (Sandoval & Millwood, 2005). Finally, students tended to use editorial inscriptions to provide data. These pre-test findings will be compared with post-test results that I obtained in March, and the next step is to intensively code and analyze the videos to provide accounts for differences, if any, between the two tests.

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