Keynote Panel

**Approaches to Studying and Modeling Learning Across Setting and Time**

Chair: Bill Penuel

Moderator: Jeremy Roschelle

Panelists: Leona Schuable
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Reed Stevens
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Theme: Consonant with the conference theme of "Learning and Becoming in Practice" this panel will deliberate on challenges facing the learning sciences as it seeks to coherently span learning in a range of settings – settings which afford diverse modalities of practice. The panel has chosen to explore this challenge by considering how the Learning Sciences might relate to the Maker Movement.

Disclaimer: Initial thoughts prepared by the panelists are shared below. However, these are NOT FOR CITATION. If you would like to cite the remarks of a panelist contact the panelist directly for permission.

Acknowledgement:

Thanks to all the participants for their willingness to put considerable time and energy into planning this panel as a collective endeavor, and not as merely a succession of position statements.

*As our fields expand to support new areas, what happens when we stretch to something like Makers -- where there is an abundance of "doing" (a different starting point than school, which traditionally was light on doing). How do we expect "making" to play out as a problematic setting where discourse/practices and content/skills will need to be related, and what do we imagine we might be able to bring from our established research to inform this setting? How do we imagine our scholarship(s) could productively interact with experts in these settings to make a difference?*

## From Leona Schauble with Rich Lehrer

Actually, school is filled with doing, if one includes mental activity in the "doing" category (as we would). Unfortunately for teachers, a lot of that doing tends to be invisible, unless one plans explicitly for ways of making it public and inspectable. Although Making more obviously entails doing, working with stuff does not necessarily provide helpful clues about the thinking behind the making. Researchers, therefore, face the challenge of figuring out how the processes or traces of construction can be recruited to "speak" about the learning and thinking guiding the activity and the production of artifacts.

Accordingly, a first thing to attend to is the norms, recurrent activity structures, and forms of representation that support learning. By norms, we mean the rules (often unspoken) about how people work together, such as the expectation that participants listen actively to each other, ask questions if someone does not understand, challenge or contribute to the ideas on the table, explain extended or complex processes in understandable ways, and the like. By activity structures, we mean cycles of prototyping, publically reviewing artifacts at various stages of creation, identifying and troubleshooting design flaws, analyzing the costs and benefits or other tradeoffs of various designs. Representational forms may include play or dramatic enactment, drawings, diagrams, blueprints, photos, products of prototyping environments and materials, journals, simulations, mathematical descriptions of all kinds.

We mention norms, activity structures, and representations first because our field often over-attends to the nature of tasks, but tends to downplay characteristics of the contexts in which tasks play out. For example, unless there is a discernible reason to create and communicate plans and revisions, people are unlikely to do so. Moreover, it takes time and practice to become proficient with the communication formats and conventions used within a field, whether those are blueprints for amateur rockets, patterns for quilts, or circuit board diagrams used by ham radio builders. Learning researchers thus need to consider whether and how the context fosters a propensity to share, evaluate, and revise designs, and whether and how learners receive opportunities to participate in the routines, media, and conventions through which the Making community represents and shares its thinking. It is a significant challenge to design a pedagogy of Making where some of the representational systems, especially mathematical descriptions and tracing structure-function relations, profit the Maker.

In many conventional classrooms, this means giving thought to developing structures that encourage new ways of interacting. For example, students designing pop-up books in a sixth grade class first inspected a number of commercially designed books and attempted to reverse-engineer some of them. Next, students turned to designing their own pop-up books, meeting regularly to review and critique each other's designs. With encouragement from the teacher, students focused on how their classmates were using or adapting familiar paper folds to produce desired effects. They also offered and received advice about how those effects met the author's stated communication and aesthetic objectives.

Moreover, it is, of course, critical to understand what is being made, along with the more fundamental question: What competencies does making at least potentially entail that we should care about? For example, the learning affordances of constructing a Lego™ car that can climb a steep hill are quite different from those involved in making a basket that has an interesting design. Moreover, because we are interested in learning, we need to think

about what developmental aspects of these competences can be profitably introduced and systematically supported for novices, bearing in mind that they may or may not be subset of (or even obviously similar to) the competencies that are practiced by experts. Performances that are so obvious to skilled practitioners that they seem invisible may yet be challenging to beginners. For example, children often find it challenging to trace mechanical transmission of force through machines, even those like simple linkages, in which every working component is totally visible. In one study, we noted that many second graders were entirely flummoxed by a request to explain why it is that when one turns the handle on an old-fashioned eggbeater through a vertical plane, the beaters turn in a horizontal plane. (The way we asked this question was, "Why is it that when I turn the handle this way [gesture direction], the beaters turn around this other way [gesture direction]?")

Again, because of our interest in development, we tend to be most interested in learning contexts that provide easy and multiple entryways to novices, but that also enable increasing and continuous levels of challenge as students' expertise grows. We disfavor modular activities that may be initially engaging but do not go anywhere. A canonical example is the "build a bridge with toothpicks" kind of challenge that seems to be so prevalent these days. Once children realize that triangular structures are more stable than those that are rectangular (IF they realize this), there is no clear way for children to understand why, and no next project to take that noticing a next step further.

In sum, as an initial pathway into studying learning in an unfamiliar context, we would worry about the norms, activity structures, and representational repertoire available for supporting (or, in some cases, impeding) learning. We would seek to identify one or more fundamental "big ideas" that are or could be thematically addressed over an extended period. "Big ideas" are structured bases of knowledge-and-performance that position participants' personal conceptual resources in coherent relation to disciplinary knowledge and practice. In Making, these often are expressed in forms of practical activity (e.g., Azevedo's description of the practical grasp of model rocketeers for testing the stability of their designs before flight, sans vectors or other mathematical descriptions) that may make (pun intended) other forms of representational description labored and unnecessary. We would seek to diagnose the resources that learners currently possess that can be recruited or adapted to the demands of the learning context, and we would try to imagine a web of both near- and long-term ideas that are potentially within reach, given an appropriate learning context or design, and that seem fruitful in generating a stronger, deeper grasp on that "big idea." This will inevitably confront us with what we value about learning and likely lead to contest with other powerful interests, especially the national academies' canonization of learning in mathematics, science, and language arts.

## From Anna Sfard

Next to my house in Tel Aviv, a new shop opened a few days ago. *3D Factory* it is called. Every so often, an accidental passer-by peeks in, hesitates for a moment, and disappears inside. After a while, you can see this person re-emerging with, well, you name it: cups, necklaces, pieces of furniture or just armfuls of unidentifiable objects of different sizes, shapes and colours. No, this is not a department store or a second hand shop. And its clients are not coming here for urgently needed commodities. People are drawn to this place by the wish to see their imagery turn flesh. This is what can happen in here thanks to the long row of 3D printers and to the rich assortment of materials that can be used for just a few shekels. How wonderful, I think to myself. From now on, you can live surrounded by things of your own making. It is mind-boggling – and new, very new. Once an educator, always an educator, I cannot help reflecting on opportunities for learning that things-making may afford. I am wondering about the kind of thinking that goes into this activity and the one that gets out of it. Yes, based on what I know from my research, thinking and making are likely to spur each other's growth. But does all this happen here? And if so, why and how?

### My task in this conversation, as I choose it to be: Proposing and applying conceptual tools for thinking about things-making as educational enterprise

Within this context, the assignment given to us by Jeremy comes handy. Indeed, according to our "worksheet", we are supposed to engage with the Maker culture and 'imagine ourselves' in the settings 'where there is an abundance of "doing"'. Once there, we are to envision ourselves 'interact[ing] with experts in these settings to make a difference.' Like myself in the 3D Factory store, Jeremy sees Makers settings as "problematic", but clearly believes they also hold a promise. It is this promise I have been trying to pin down. Aware that new situations require new conceptual tools, I will first tackle the question of *how to think about the new educational opportunities inherent in the increasingly popular things-making*. After proposing a set of conceptual tools, I will apply them in the attempt to figure out these opportunities. The first thing to do, however, is to clarify what should count in this context as *opportunity*.

### Introducing the principle of learning-by-making

The answer to this last query depends on the *kind of difference* we wish to make. If we decide to pursue Maker activities as an educational goal in its own right, the desired difference will be in the accessibility and quality of these activities. But we can also see things-making as means rather than ends – as something to be used as a tool for making a difference in, say, the learning of mathematic and science. It is this latter interpretation that will frame my further reflections: I will be talking here about *learning-by-making*.

This choice may raise some brows. First, considering the current rhetoric of "nothing is going to be tomorrow the same as it is today" and the constant warnings

about imminent educational revolution, opting for traditional goals may appear less than imaginative. This criticism does not deter me. While waiting for the revolution to come, we may as well grab any available opportunity for change and improvement. Second, some critics may see the principle of learning-by-making as not much different from that of *learning-by-doing*[1], with which we have been familiar at least since Papert's inspiring manifesto known as *Mindstorms*.[2] As before, I beg to differ. The activity of making can be defined as one that aims at producing material things, which is not a general property of all doing. Thus, whereas every case of learning-by-making is also a case of learning-by-doing, the reverse does not seem to hold. And there are other features that render learning-by-making special. According to Wikipedia, things-making, as understood by maker community, involves "informal, networked, peer-led, and shared learning motivated by fun and self-fulfillment", and also "novel applications of technologies, and the exploration of intersections between traditionally separate domains and ways of working". Once again, not every doing bears all these characteristics.[3]

## Conceptual tools: Discursive vision of learning-by-making

I believe that *the discursive framework* that I have been using while studying mathematics learning (Sfard, 2008) may be helpful also in explain where the educational potential of learning-by-making comes from and in trying to decide how we can harness this potential in the service of STEM learning. Let me outline this approach very briefly.

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[1] Some languages make no distinction between *doing* and *making* (as do Polish and Hebrew, for instance), and this may strengthen the impression that there is no difference between learning-by-doing and learning-by-making.

[2] According to the principle of *learning-by-doing*, hands-on-experience and the active engagement in the types of activities that utilize or help in producing what is being learned improve students' access to such school disciplines as science or mathematics. Its roots can be found, among others, in the deluge of cross-cultural and cross-situational studies that have shown that even unschooled people can become impressively skilful in certain kinds of calculations, provided they engage in these activities in response to their everyday needs and on everyday basis (Lave, 1988; Scribner, 1997; Cole, 1996). But the idea goes back farther than that. It can be seen as inspired by Piaget's claim about our own actions as the primary source of any abstraction, as well as by Vygotsky's insistence that learning means gaining mastery over historically established forms of activity. Thus, whatever school of thought you belong to, you must agree that *doing things* is a necessary, inextricable ingredient of the process of learning.

[3] If I have voted for the new-means-to-traditional-ends option, it is also because I doubt whether we are ready to pursue things-making as an activity to be learned, that is, as the object of learning in its own right. I believe that before any step is taken in this direction, a deep thought must given to the question of what kinds of needs should be our guide and what kinds of making deserve being included. As far as I am concerned, the slogan "The art of making should be appreciated and celebrated," which the advocates of maker culture wrote on their banner (see http://en.wikipedia.org/wiki/Maker_culture; retrieved on 30 April 2014) does not go without saying. In these times of our planet's accelerated wilting, we can no longer deny that our love for things has its price.

As argued by socio-cultural thinkers, the type of learning that makes humans human can be seen as the process of developing specifically human ways of doing things. Talking, thinking mathematically, producing artifacts and conference-going are among such unmistakably human activities. Note that according to this definition, the *learner* may be either an individual person or any human collective. In other words, we can speak of learning on either individual-ontogenetic or societal-historical level. This latter type of learning, one that expresses itself in the fact that human activities change along history, is unique to people.

Depending on the nature of change they bring, all human forms of doing can be roughly divided into two types. The first category, to be referred to as *practical*, consists of activities that produce changes in material objects or in relations between such objects.[4] Things-making is thus a type of practical activity. The other category, traditionally cultivated in schools and universities, is commonly known as "developing knowledge", but since it can be viewed as the process of producing and endorsing useful stories about the world, I prefer to call it *discursive*. Since in our daily lives discursive and practical activities are tightly interconnected, telling them apart may sometimes be difficult.

That discourses and things-making are intricately interrelated has been known ever since the unfortunate project of building the famous tower in Babel. Just to remind, that eventually unfortunate undertaking began with the distinctly discursive activity of imaging how empowering it might be for people to have an access to a sky-high structure; it then unexpectedly ended when the worker's were deprived of common language. Unsupported by discourse, the project of making was doomed to failure. But the relation between discursive and practical activities is not merely one of mutual support. According to discursive approach, *these two forms of human doing are constantly spurring each other's development*. In particular, our stories inspire and inform ever more complex things-making, whereas things-making spurs further storytelling and induces the development of discourses within which these narratives are forged. The stories and artifacts that result from this cyclic process serve as repositories of complexity and propagators of innovation. In particular, these are the devices that carry the innovation from one generation to another, thus making societal learning possible.

## Discursive argument for learning-by-making

This last tenet justifies the belief in the educational potential of learning-by-making. Doing in general, and making in particular, emerge from this account as major sources of meaningfulness: by seeing how abstract mathematical and scientific stories are doing some useful, tangible work, the learners will hopefully realize that crafting these stories is a

[4] This is to hold for both natural and human environment. Thus, an activity that causes a consequential change in relations between people, such as wedding ceremony, will count for the sake of this discussion as a case of practical activity.

worthwhile endeavour. Paradoxically, the learning-inspiring interaction between discourses and other, more practical human activities can rarely be seen in those places that constitute the main settings of individual learning: the schools. Re-marrying discourses and other forms of doing by engaging the learners in things-making may thus be the right thing to do.

Some may say that such reconnection is exactly what we have been trying to do ever since the birth of learning-by-doing pedagogy. In response, let me argue that things-making, this special sub-category of doing that is still almost entirely absent from schools, has some special strengths to offer. To begin with, it has a particular potential for motivating the learner. Just think about the attractiveness of the new materials and cutting-edge technologies that the students are encouraged to use, and also about the fact that the goal of making activity is to produce objects that the learners may be happy to possess. Second, the elusive feature known as "authenticity" that is often seen as a condition of successful participation is less likely to be lost in the transition from informal to formal settings than is the case for those forms of doing that stop short of producing any tangible changes in environment. Finally, the student who aims at a specific material product is more likely to act autonomously than is the learner of traditional mathematics or science. It is the thing-in-making that overtakes the role of the teacher while providing an instant feed-back to the maker's actions.

By now, I hope to have made a strong case for the pedagogy of learning-by-making. But lest my argument comes through as too strong, I will now switch to the role of devil's advocate. This, unfortunately, may be only too easy to do. While the advantages of things-making seem clear, it is much less so when it comes to the question of how to make this pedagogy work. I will now present some open questions about the feasibility of learning-by-making. While doing so, I hope to be forgiven for not proposing any solutions. I will be happy for you to believe that the only reason for this abstention is the lack of time.

## Problematizing learning-by-making

The first question to ask is whether, and under what conditions, things-making would really advance those discourses that we wish to promote. Co-constitutive nature of discourses and Maker activities may be clearly visible at the societal-historical level, but there is no automatic translation of societal-historical features to the individual-ontogentic level. Think, for instance, about the fact that when trying to make an object, people may be tinkering rather than applying (and extending, if necessary!) their mathematical and scientific knowledge (Kantorovitch, 1993).

Even if we believe that under some conditions mathematical and scientific discourses are likely to benefit from making, can these conditions be created either in school or beyond? The most promising way for the student to capitalize on discourse-practice interdependence is to be exposed to a full cycle of the co-constitutive interactions between discursive and practical activities. In the course of history, such cycles would often take years, decades or centuries. Is any "miniature"

version available that would fit into scanty school timeframes? Can we organize learning so as to show both how discourse enables and advances things-making and how this latter activity reciprocates with pushing the discourse forward? Won't the whole advantage of making be lost if we only show small segments of such cycle, detached from those of its elements that render the discourse meaningful in the eyes of beholder?

Yet another question is how to incorporate things-making in STEM education. It seems that for this to happen, some restructuring of curricula is needed. To use Piaget's terms, bringing things-making to school is not merely a matter of assimilation, but rather requires a major accommodation. To begin with, it may be difficult to find workable things-making projects that would fit squarely into a single school subject. Such projects tend to involve a whole range of discourse. This multi-discursivity is certainly an advantage, but may also be a true challenge. It is not easy to create substantial opportunities for students' productive participation in a number of specialized discourses, while also making sure that in all of them the entry conditions are not too far removed from the current level of the students' competencies. Another question to consider is how to incorporate these projects into school programs without killing the joy of the spontaneous things-making. Finally, we must be wary of the only too common "Midas effect", one that can be observed whenever the educators, infatuated with a seemingly "golden" pedagogic idea, try to turn into gold whatever comes their way.

## Coda

In this brief presentation, I claimed to be talking about things-making as new means to old ends. This, of course, was not entirely accurate. Under the influence of new means, the ends must eventually change as well. How this may happen and where the changes may eventually lead us to must be left for future meetings.

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**From Reed Stevens:**

The learning sciences got started on too narrow a base of phenomena; of this there can be no question. It was mostly about school math and science; then after a while school literacy and history received a little attention. In his book *Cognition in the Wild*, Ed Hutchins describes a similar distorting omission in cognitive science's origin story, which built its initial account of cognition without culture (and therefore largely with communication and joint action), without a sensing body, with emotion.

'Making' can therefore be seen as a refreshing stretch of topic for the learning sciences. And certainly 'the maker movement' is being advertised, and sold, as something very new in education, not unlike video games were about a decade ago. But I think the focus on making *as a topic or subject* is not quite right, and so in this commentary, I will argue how we might start to see and study 'making' and the 'maker movement' as learning scientists in ways that treat making less a topic than a distinctive way of having and organizing experience.

Yesterday I made: a baked egg dish by myself, a model of my house out of Legos with my ten year old son, a rough IMovie parodying a Lorde video with my twelve year old daughter, and a plan for a summer trip with my wife (whose age I suspect she would rather I not reveal). If this last example seems too metaphoric, it would seem less so if you saw that what we made was a physical inscription made of lines, boxes, words, numbers, and icons; layered with dates, locations, critical time-sensitive points, questions, and so on.

Are all of these cases of 'making'? At least a couple of them seem to tie to what 'making' in the sense of 'maker spaces' seem to be about, involving engineered materials like Legos and software like IMovie. In both cases, these tools and materials were used toward a purpose of creating a digital or tangible object. But would we not count making the egg dish and the handwritten and hand-drawn travel plan as making? Because the materials and tools are not new? That seems the wrong basis for excluding them. And what if I share that those two 'making' activities at least felt far more new in the sense of invention; I had never made this egg dish before; I combined bits of this and that from the refrigerator and garden and cooked it two ways (as an experiment), and our trip plan was pulled together from a lot of heterogeneous materials (e.g. memory, the internet, a map from a relative, and travel notes from a friend); we followed no one else's script about where we would travel. On the other hand, the IMovie was a class assignment (for a parody), built on the musical structures of well-known song by Lorde, using

commercial software that constrains the movie making process, at least compared to other means for making movies. The Lego house we built was made of standardized pieces, designed for making architecture models, and what we were modeling was our own home, which we were sitting inside and observing. So on at least some inventiveness dimension, the IMovie and the Lego house were arguably *less* 'maker'-y than the egg dish and travel planning since they involved more 'copying'.

My point is that we don't know what to count as making yet (even when confronted with a small one-day idiosyncratic sample from my life). Should we be paying attention to the degree of inventiveness, self direction, tangibility, timescale, the realizing of a physical object, the use of specific kinds of production tools or something else?

So my first suggestion is a simple one that I follow in my own work; let's start with some field studies of 'making' in a *wide* range of different contexts, being wary not to narrow our focus too quickly and remembering the dangers of implicit cultural bias in what we count as 'making'. Let's explore what counts as making, both to us as professional learning scientists, but following an ethnomethodological heuristic, what counts within the groups and communities we are studying (Stevens, 2000; Stevens, 2010).

Having some concrete cases to think with makes a big difference in conceptualizing future work, at least it does for me. This is an approach I took with some colleagues a decade ago when there was a burst of wide enthusiasm for video games as learning environments similar to that we see for 'making' at this cultural moment. At the time, we noticed that, despite the enthusiasm, there were nearly no field studies of naturally-occurring video game play itself. One of the things we discovered in that study can be related to my initial suggestion not to see 'making' as a topic or subject but more a form of organizing experience; we discovered that the quality and variation of learning in our video game study depended heavily on the interactionally organized contexts of play, what we called 'learning arrangements' (Stevens, Satwicz, & McCarthy, 2007). We found that what goes on 'in room' (the so-called context) matters as much or more as what goes on 'in game' (the so-called content). So it may not be that getting some narrowed definition of 'making' right matters most for learning as much as getting right the social, spatial, material, evaluative, and hedonic organization of the contexts in which 'making' takes place. For brevity, let's call this organization an 'infrastructure for learning'.

I can connect this point about the importance of learning infrastructure to the research and development project to which I devote much of my current time called FUSE Studios, which is a designed learning experience, differing from the everyday examples I gave earlier. Most, I think, would recognize FUSE Studios as a "making" experiencein the narrow contemporary sense, since it involves tools and things like 3D printers, programmable robots, arduinos, LEDs and the like; youth participants in FUSE Studios typically make a tangible or digital object that meets some functional criteria. However, the way a basic unit of FUSE experience differs in at least one important regard from what I have seen in maker spaces and at maker faires, since making in FUSE Studios is largely structured by a sequence of challenges that level-up like video games. Despite this difference, FUSE and other 'making' experiences have enough in common and offer the learning sciences some opportunities for asking new and compelling research questions.

Taking FUSE as an example, these new questions will be the focus of the remainder of my commentary. In our FUSE research studies, we are able to ask different kinds of questions than we can ask of typical school-based learning experiences. The reason—as is my developing theme—is because of the different ways we have organized FUSE experiences from typical classroom experiences. FUSE Studios are environments organized around a set of challenge sequences that 'level up' the way video games do. Youth participants have control and choice, a big difference from their experiences in school. Participants choose whether to work alone or with others; they choose which challenge sequences they will explore and they choose whether and when they stop with a challenge sequence and move to another. Another difference from school is that FUSE participants are not graded; instead they self document their completion of challenges, which unlocks subsequent challenges in a sequence. Adults are asked to play a facilitative or coaching role; we want youth participants to 'pull' information and guidance from adults rather than have it 'pushed' on them (cf. Becker, 1972). But largely, our hope and goal is that help, teaching, and guidance will become—following the lead of projects like the Fifth Dimension (Cole, 19xx)— the job of other more experienced youth participants.

The kinds of distinctive questions we are asking in FUSE, which seem ripe

for asking in other sorts of organized 'making' experiences, involve issues that are *so difficult* to ask in meaningful ways of learning experiences in compulsory schooling. These include persistence, interest development,

adaptive, creative flexibility in problem solving, and learning to 'fail' productively. Here I can't resist quoting my favorite writer on education, James Herndon.

> *That is why the school cannot ever learn anything about its students…As long as you can threaten people, you can't tell whether or not they really want to do what you are proposing that they do. You can't tell if they are inspired by it, you can't tell if they learn anything from it, you can't tell if they would keep on doing it if you weren't threatening them… all you can tell is, they'd rather come t***o** *your class than go to jail.*
>
> (**James Herndon, 1971: 97-98**)

Just as FUSE and other 'making' environments invite asking questions other than whether and how well young people 'get' what they are taught, these environments also disrupt and challenge views of 'teaching' as we know it from compulsory schooling. These contexts invite questions of how to support young people's emergent learning, resource finding, their persistence, their flexibility, and their developing interests. How we are trying to build accounts of these phenomena (both with regard to youth experience and adult support) in FUSE is a longer story and work most definitely in progress. My point here is that 'making', understood with an expansive sense of what counts as making, invites new, exciting questions for the learning sciences, ones that many of us might feel more satisfied trying to answer than whether we're raised test scores or met this season's new curriculum standard.

## From Beth Warren

I approached this task with a desire to map in a very preliminary way some of the varied territory of making as it is being explored and conceptualized in different fields: education, anthropology, design and engineering, and Indigenous art. I see this as a crucial step in any endeavor to locate the place of learning sciences research in relation to emerging cultures of making. Without a sense of the territory, including the varied ontological, epistemological, aesthetic and ethical commitments entailed, I worry that we may domesticate making to existing paradigms of theory, research and design, and thereby limit possibilities for imagining new modes of engaged learning or understanding in practice (Lave, 1990).

In a modest effort to resist that domestication, I have spent the last couple of weeks reading. I don't know if I've been reading broadly or narrowly, along a single path or crisscrossing many paths. This is because I don't yet have a firm grasp of the territory in which I've been wandering. However, I am sensing that the territory includes varied framings of making that suggest significant implications for learning, development and design. Here I will gloss some of the territory of making that I have encountered in my reading thus far, knowing that I am going to blur, conflate and oversimplify things in my haste to read. I will leave many loose threads and unsteady thoughts. I will probably re-inscribe dichotomies I am hoping eventually to disrupt. But I also hope this ragged reflection will help with the goal of prompting and provoking conversation on the relationship of our field to emerging cultures of making. In what follows I touch on four cultures of making I have encountered through my reading. While my inclinations toward one or the other may be obvious, I do not intend this as a critique so much as an exploration of some important questions and issues.

The first take on making is from *Design Make Play* (Honey & Kanter, 2013), which aligns with the *Framework for K-12 Science Education* and President Obama's *Educate to Innovate* campaign. In their introduction, Honey & Kanter define what it means to make in this way:

> Make—to build or adapt objects by hand, for the simple personal pleasure of figuring out how things work. Long before the rules of science were written down, people engaged with scientific disciplines by making things; things to help us do what we need to do, or things that are just fun. A quiet revolution is unfolding in communities across the country that is deeply rooted in this defining characteristic of our species and that has the potential to transform science learning. Known as the *Maker Movement*…makers are drawn together by a shared delight in the magic of tinkering, hacking, creating, and reusing materials and technology… (Honey & Kanter, 2013, p. 4)

In elaborating this characterization, Honey & Kanter connect an older tradition of science with the modern Maker Movement. They invoke a discourse of magic and delight in the

ways that makers explore materials and technology. I am leaving a lot out here from Honey & Kanter's introduction and the rest of the volume in order to highlight a framing of making as related to human pleasure, specifically, objects made being valued in relation to the satisfaction they bring to the individual maker's interest or curiosity. Making, in this view, is driven by a desire to understand how things work. (Now you know what I meant when I said I would be oversimplifying.)

The second take is from Tim Ingold (2013). In his book, *Making*, he is concerned, among many things, with distinguishing objects from materials or what he calls *making as a project* from *making as a process of growth*.

> We are accustomed to think of making as a *project*. This is to start with an idea in mind, of what we want to achieve, and with a supply of the raw material needed to achieve it. And it is to finish at the moment when the material has taken on the intended form. At this point, we say, we have produced an *artefact*. A nodule of stone has become an axe, a lump of clay a pot, a molten metal a sword. (p. 20)

In this view of making as project, practitioners impose conceptual representations of form (internal to the mind) upon an external material world (pp. 20-21). This "hylomorphic model" seems strongly related to the ways in which "doing" within STEM in schooling has tended to be pursued, that is, within a defined process with expected products and outcomes.

Ingold proposes an alternative to the hylomorphic model:

> I want to think of making, instead, as a process of *growth*. This is to place the maker from the outset as a participant in amongst a world of active materials. These materials are what he has to work with, and in the process of making he 'joins forces' with them, bringing them together or splitting them apart, synthesising and distilling, in anticipation of what might emerge. The maker's ambitions, in this understanding, are altogether more humble than those implied by the hylomorphic model. Far from standing aloof, imposing his designs on a world that is ready and waiting to receive them, the most he can do is to intervene in worldly processes that are already going on, and which give rise to the forms of the living world that we see all around us – in plants and animals, in waves of water, snow and sand, in rocks and clouds – adding his own impetus to the forces and energies in play. (p. 21)

For Ingold, both organisms and artefacts arise through a form-generating process, one major difference being the extent of human involvement. He frames making as a confluence of forces and materials rather than as a transposition from mental image to material object. He does not deny that the maker may have an idea in mind of what he wants to make, but does argue that the idea or form does not create the work. Rather it is the engagement with materials – the *relations* between maker and materials – that generates the work. This fits with the practice and discourse of artists with whom my colleagues and I have lately been working. With this framing, Ingold, I believe, sides with artists and artisans who "to know materials…have to follow them" (p. 31).

> Their every technical gesture is a question, to which the material responds according to its bent. In following their materials, practitioners do not so much *interact* as *correspond* with them. (p. 31)

Invoking the Swiss architect Peter Zumthor, Ingold emphasizes the idea that "there are a thousand different possibilities in one material alone" (Zumthor, 2006 quoted in Ingold, 2013, p. 30). And, therefore, I might add, many possible trajectories in any process of making, many possible collaborations *with* any one material to see what it will do. This way of framing making is rather different, I think, than one in which making is for the pleasure of figuring out how an object works. Ontologically and epistemologically, they stand on different ground. These differences matter for design within a learning sciences perspective, that is, in how we construe relations between makers, materials, and the processes in which they engage.

The third take on making connects with—in order to subvert—the design and engineering culture that dominates the modern socio-technical landscape. Here I focus on the design work of the anonymous Institute for Applied Autonomy (IAA, see http://www.appliedautonomy.com). Rooted in engineering and artistic discourse integrated with cultural criticism, IAA works from the premise that any technology or product involves a set of social relationships. In its projects, IAA sets out to invert established modes of authority—mostly related to surveillance and the privatization of public space—through the design, fabrication and deployment of experimental systems in public spaces. Their projects play a dual role. Consistent with art practice, they serve as pedagogical tools to provoke public engagement with critical issues. Consistent with hacker practice, their projects function as tools that can be (and have been) used to mobilize against state authority.

> As an organization, the IAA is an exercise in tactical aesthetics – we use the visual and rhetorical devices of sanctioned research organisations in an elaborate performance aimed at infiltrating engineering culture…Our critique of engineering practice thus comes from within engineering culture, and is given material weight by the production of working artifacts.
>
> While there is a long history of artists and social theorists questioning relationships between technology and society, there is an equally long history of engineers ignoring art and social theory. By acting as engineers who address contentious political issues, we undermine the normalised ambivalence that characterizes engineering practice. The works thus act as Trojan horses, carrying our critique through the gates of detachment that guard engineers against taking responsibility for the products of their labour. In lieu of ambivalence, we offer the engineering community the image of an 'engaged engineering' that works diligently in the service of freedom and human dignity, and takes responsibility for the world it helps create. (www.surveillance-and-society.org/articles1/iaa.pdf, p. 99)

As an example, IAA has created iSee, which is a mapping application that allows users to visualize the distribution of surveillance cameras in urban centers such as Manhattan and London, and then to follow "paths of least surveillance" for navigating in and across these cities by avoiding surveillance cams (http://www.appliedautonomy.com/isee.html).

Putting aside the question of whether this is an effective way to actually navigate Manhattan and London, iSee is intended as a kind of discursive tool that can provoke conversation about issues of privacy, security, surveillance and democracy. iSee and other IAA projects are designed *for the street* to incite unscripted discussion of critical issues of individual agency and social accountability, conversations different from those fostered in "protected environments" such as schools, museums and galleries, or labs.

The visual, communication, and robotics interventions created by IAA and fellow designers represent socially engaged forms of interaction design. These interventions are focused on systems level activity to re-imagine networks of relationships between people, institutions, and large problems of local, national and global concern (http://vimeo.com/22100021). This approach applies equally to problems of surveillance as to problems of water scarcity and use. Tad Hirsch, the director of the Public Practice Studio in Seattle, makes the point that in many of these kinds of projects the heavy lifting in terms of innovation is everything going on around the technology or tool rather than the tool itself—the social networks of relationships, in other words. For this reason, among others, these technologies tend to be developed using a participatory design approach that draws on the expertise of communities of people who have been working on the focal problems for a long time and aims at imagining the emerging and sometimes not yet articulated desires of these communities. Within this framing, making extends well beyond any individual and implies a kind of transdisciplinary way of thinking grounded in new kinds of collaborations, new sets of knowledge, and new kinds of practices mobilized to contest the normative social order. It suggests the importance of opening our field to influences and sensibilities beyond what we know and value in order to frame new potentialities for learning and social change.

Lastly, I turn to Indigenous art as a fourth take on making. I thank my colleague, Megan Bang, for pointing me to the current special issue of *Decolonization: Indigeneity, Education & Society* (2014, *3*(1)), which is focused on Indigenous Art, Aesthetics and Decolonial Struggle. This being my initiation into this work, I approach it with humility. While I cannot claim any depth of understanding, I feel its significance in relation to the framings already discussed and to the larger question of the place of learning sciences research in emerging cultures of making (which admittedly do not necessarily connect with art and artistic practice).

In the introduction to the special issue, Jarrett Martineau and Eric Ritskes, make it clear that contestation is a potent theme in Indigenous art, namely, in the disruption of political and aesthetic hegemony. But contestation coupled to creation and freedom from the confining logic of Western ways of knowing, sensing, and making. They write:

> Indigenous art evokes a fugitive aesthetic that, in its decolonial ruptural forms, refuses the struggle for better or more inclusion and recognition (Coulthard, 2007) and, instead, chooses refusal and flight as modes of freedom…The freedom

> realized through flight and refusal is the freedom to imagine and create an elsewhere in the here; a present future beyond the imaginative and territorial bounds of colonialism. It is a performance of other worlds, an embodied practice of flight. The fugitive aesthetic is not an abdication of contention and struggle; it is a reorientation toward freedom in movement, against the limits of colonial knowing and sensing. It seeks to limn the margins of land, culture and consciousness for potential exits, for creative spaces of departure and renewal. Indigenous art not only confronts and reveals structures of power and the failures of settler colonialism (which is evidenced by the continuing presence of Indigenous peoples), it fights to realize Indigenous alternatives. (Martineau & Ritskes, 2014, p. iv)

As Martineau & Ritskes argue, the fugitive aesthetic, even as it is rooted in a politics of land and place, expresses a trajectory away from any framing within a colonial mindset. What might this idea of a fugitive aesthetic imply for the learning sciences? Among other things, it means that creative making cannot be contained within a multicultural or other 'equity and diversity' frame. Nor can it be confined within a European American understanding of art and aesthetics (in relation to making as well as meaning-making or interpretive practice).

In one article in the special issue, the Anishinabekwe/artist/researcher, Celeste Pedri-Spade, shares *Nametoo: Evidence that he/she is/was present*, a collection of photographic artworks created with her family, through which she describes a "decolonial aesthetic that is process based and emerges out of relationships with self, others, materials/tools, and the lands in which we are situated" (Pedri-Spade, 2014, p. 73). Her work not only disrupts colonial histories through counter-narrative but, in the intentional layering of images blended together, engages viewers in a paradoxical process—as they are invited to distinguish the blended images, they find it very difficult to do so. Pedri-Spade explains:

> This intentional layering implicates the viewer because as the viewer looks at the photographs, they attempt to separate or dissect the images—to "make out" each exposure independently from the other. Here, I want the viewer to reflect on ideas of separation, breaking apart, and dislocation, and critically reflect on how they may or may not be participating in the continued displacement of Aboriginal people…Garneau (2013) writes that artwork that engages decolonial aesthetics is about stimulating and disrupting the senses and they are "mentally indigestible…they encourage people to puzzle with them and learn what they need of them" (p.21). (Pedri-Spade, 2014, p. 94)

Artwork like Pedri-Spade's thus engages an interpretive repertoire that calls on an expansive attentiveness to relationships across scales of time and space.

I should say more here, but I have run out of time. Let me close with this. What I am trying to suggest as a bottom line here is that how we, as learning scientists, frame making matters. With which histories, voices, perspectives, and practices will we puzzle as we intervene in making as a creative movement with varied potentials for learning, development and social change?

**From Marianne Wiser**

Marianne did not provide written remarks. She will focus on a critical perspective; perhaps trying to connect Learning Sciences to something like Makers isn't productive.