Students' Perceptions of Giving and Receiving Design Critiques in an Online Learning Environment

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Abstract: A common practice in design education settings is participation in crits, or design critiques, in which critical feedback is given about creative works in progress. This paper presents a rationale for Studio Zone, a web-based environment to support design critiques, and results of a study of the software in use in a graduate software design course. We focus on how students perceived design critiques in general, and how they perceived Studio Zone as a tool for participating in critiques in an asynchronous, online environment. Results revealed that critique was a valued activity and that participation in critiques was shaped by social factors such as rapport and perceptions of shared concepts of critique, as well as the constraints of the technology. Students perceived asynchronous critiquing in Studio Zone as providing certain valuable affordances while also voicing some reservations about giving critiques to peers online. These results suggest implications for how critiques should be structured and guided within the context of a course in which students engage in asynchronous and/or face-to-face design critiques.

Keywords: design, reflection, critique, learning environments

> Ultimately, the care with which we treat one another within our organization is the source of empowerment, and provides the foundation for good design. (De Young, 1996, p. 255)

In design education settings such as architecture studios, participation in "design critiques," or reviews of creative works, are considered essential to learning how to design (Shaffer, 1999). De Young s statement above highlights the importance of social interaction in a design environment; being able to communicate and support others is just as important as knowing design principles and having design skills. Focusing on this social aspect of designing, this study explores the potential of web-based technology to provide beginning designers an alternative environment for participating in design critiques.

Studio Zone is a web site that allows students to present digital images of their designs and to post comments asynchronously. It provides a shared space for capturing designs in progress and scaffolds the processes of presenting designs and responding to others' designs through the use of guiding questions and prompts. The two main pedagogical goals of the software are to foster students' ability to reflect on their designs and to enhance opportunities for students to support and learn from each other through design critiques.

Primarily addressing the second goal of providing a supportive learning environment, this study set out to describe and analyze how users perceived Studio Zone as a place to give and receive design critiques. In this paper, we present a rationale for Studio Zone and focus on how students in a graduate-level educational software design course perceived Studio Zone as a tool for learning to critique design. The implications of these results indicate ways in which critiques can be structured and guided within a design course, whether an online critiquing tool is used or not.

Scaffolded Computer-Based Learning Environments

The learning technologies that are most relevant to the study reported here are computer-based learning environments that have mostly been used in science education such as Computer Supported Intentional Learning Environments (CSILE) (Scardamalia & Bereiter, 1991), the Knowledge Integration Environment (KIE) (Linn, 1995), and the Progress Portfolio (Loh, et. al., 1998). In general, they aim to promote deep concept understanding and to develop scientific inquiry skills by providing procedural and cognitive scaffolding. Scaffolding (Collins, Brown & Newman, 1989) is a form of guidance that helps students carry out tasks that might ordinarily be too difficult. For example, CSILE provides cognitive scaffolding by prompting students thinking as they participate in asynchronous discussions with sentence starters such as, My theory is . Similarly, in the Knowledge Integration Environment (KIE), students science investigations are guided with procedural prompts, as well as cognitive guidance in the form of prompts and hints (Bell, Davis & Linn, 1995). The scaffolding is designed to help students conceptualize scientific

investigation in the way that experts do. The Progress Portfolio scaffolds the process of scientific inquiry by providing a workspace in which to document, manage, and communicate about the [scientific] investigation (Loh, et. al., 1998, p. 2).

While these computer-based environments aim to help students become reflective *inquirers* in various ways, this research explores how the same ideas can be applied toward developing students as reflective *designers.* The research on computer-based learning environments for science education suggests a promising avenue for similar work in other domains such as design.

Computer-based Learning Environments for Design

Researchers have also highlighted the importance of reflection in design-oriented domains. (e.g., Kafai, 1995; Shaffer, 1999; Gal, 1996) For example, the use of design diaries (Puntambekar & Kolodner, 1998) and role-plays (Rowland, Fixl & Yung, 1992) have been offered as ways to promote reflection in design learning contexts.

Perhaps the most prominent research in this area is underway at the Georgia Institute of Technology (Kolodner et. al., 1998; Puntambekar & Kolodner, 1998; Shabo, Guzdial & Stasko, 1999). Researchers have been engaged in the development of a Supportive Multi-User Interactive Learning Environment (SMILE), a suite of technology tools to support collaboration and reflection during problem-based learning, project-based learning, and learning from design (Nagel & Kolodner, 2000). Like the computer-based learning environments described in the previous section, SMILE scaffolds students in a variety of tasks, such as proposing solutions and explaining test results. One of the SMILE tools, the Design Discussion Area (DDA) is designed to support students presentation and discussion of design plans and results. One way the research reported in this paper connects to the DDA is the common focus on supporting students presentation and response to design. Thus, while there is some key research that explores how technology can support design critiques, it is limited.

Theoretical Basis of Studio Zone

A basic theoretical idea underlying the design of Studio Zone is social constructivist pedagogy, which values reflection and articulation of thinking in a social context. Collins, Brown and Newman (1989) highlight the importance of reflection in their theory of cognitive apprenticeship. In their model, reflection enables students to compare their own problem-solving processes with those of an expert, another student, and ultimately, an internal cognitive model of expertise (p. 482-483). By articulating thinking, students clarify their understandings as well as make their thinking accessible to others.

The work of Sch n (1983, 1985) and Shaffer (1999) also informs the theoretical basis of Studio Zone. Their work describes aspects of reflection that are essential to learning in architecture studios. Specifically, Sch n and Shaffer identify the desk crit, or design critique between master architect and student, as an interaction in which the student learns to adopt expert design practices. Shaffer emphasizes the "expressive" nature of design critiques, describing that expression as "the process by which thoughts, emotions, or sensations (internal mental states, or incepts) are reflected in words, gestures, or physical creations (external states, or incepts)." This model of social interaction between student and instructor involves a critical conversation about the student's design, and usually involves both people working towards solving a problem.

Connected to this notion of design critiques is Vygotsky s idea of the zone of proximal development, or ZPD (Vygotsky, 1979). In his view, the use of speech is considered a tool for connecting people and for achieving goals. For a learner to develop skills that she could not ordinarily perform on her own, the internalization of socialized speech depends on interaction with a more skilled person. From this premise comes the zone of proximal development, which can be defined as:

> the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers (Vygotsky, p. 86).

Hence, this study views learning in design critiques as a ZPD, assuming one participant is more knowledgeable in some respect compared to the other. As people with different levels of experience and skills interact with each other, zones of proximal development are dynamically created. Thus, zones of learning potential are not only created by interactions between student and instructor. Depending on the task at hand, a particular student can theoretically be located in a higher or lower point in the zone. Assuming that students have various individual strengths and weaknesses, peer interaction can create valuable opportunities for learning.

Goals and Features of Studio Zone

Studio Zone serves as a virtual critique space that structures and guides students thinking as they present and respond to work at various points during the course of a design project. By saving students representations of designs over time (and the discussions of those designs), Studio Zone also captures the design process itself. This can be valuable not only as a reflective tool for students while they are designing, but also for keeping a store of case studies. The software can be used for instruction in a variety of design oriented domains such as graphic design or even studio art. In the study reported here, students were studying educational software design.

A general goal of the Studio Zone software is to develop students ability to create, reflect on, and critique design. Acknowledging that presenting work and accepting criticism can at times be daunting to students, Studio Zone aims to create opportunities for students to share experiences and provide general social support in the way of encouragement, suggestions, and/or technical advice. An important cognitive objective is to help students become more adept at making critical responses to designs. It is expected that fostering the ability to reflect on and respond to design will be valuable for developing design skills.

On a practical level, the accessibility of the web provides students a forum in which they can interact outside of normal class meetings. Hence, Studio Zone is designed to extend opportunities for social interaction. Providing a way for students to communicate asynchronously with each other and with the instructor can be important for a typical design-oriented class such as the one featured in this study since face-to-face time is often needed for group meetings and learning specific skills. Instructors often need to spend time meeting with students individually to review work. The accessibility of a web-based environment also allows for enhanced access to participation in design critiques.

Two main features of the Studio Zone software that are designed to support the learning goals are the *assignment discussion space* and the *guiding questions and prompts*. As students work on their design projects, they can participate in design critiques online in the assignment discussion space. To present work to the rest of the class in Studio Zone, students can post images and text that describe the current state of their work. Students can then make comments in response to the posted designs. This activity structure allows students to create records of their design work at each step of a project. It allows students to create a visual record of a project from initial ideas, through revisions, to final product. By making these steps explicit and accessible by all participants, Studio Zone aims to make the iterative process of design visible. Thus, by making aspects of design explicit and accessible, these representations can then become tools for thinking. In effect, they can become part of the reflective conversation among students.

Studio Zone's *guiding questions and prompts* address the cognitive goal of developing the ability to reflect on and critique design. By providing cognitive supports in the form of guiding questions and prompts, Studio Zone encourages students to articulate their thinking at various points of the design process. These guides can be customized by the instructor and appear as students post to the site. These provide strategies for assessing their own work and responding to the work of others. For example, as a student composes her post to present a design, she might see the guiding questions, What is you rationale for your choice of layout in this design? or, What was your target user group? Prompts in the form of sentence starters might also appear. For example, when a student is responding to peers work, he might see the text, "The first thing I notice about the layout is " or "An alternative way of handling the issue might be "

In addition to these main features, Studio Zone allows students to view portfolios of their work collected online. A set of administration functions also allows the instructor to create new assignments, manage usernames and passwords, and monitor online activity.

Research Design

The setting for the study was a Master s level course on educational software design that lasted for 14 weeks. The class met for three hours once per week. There were 13 students in the course (9 females and 4 males). These students were all students in the Educational Technology program and had different levels of design experience.

Primary data sources included student and instructor interviews, posted writing and images on the Studio Zone web site, and survey data. Interview protocols were designed to gain information about (a) the participant s background and experiences related to design, (b) his or her experiences learning design in the course, and (c) his or her experiences in Studio Zone and in critiques in class. In the instructor s interview, we included questions about her goals for the class, as well as her approaches to teaching design of

educational software. We collected all postings on Studio Zone, including (a) presentations of project groups storyboard images and their written explanations of those images (n=25), and (b) students posted responses to the presentations (n=41).

During the first few weeks of the design course, students were asked to create storyboards, or visual representations of the computer interface. Students working in their project groups were to post digital images of at least four screens from their storyboards along with descriptive text. Then, students logged in to Studio Zone individually and were asked to critique at least one storyboard from another group. The instructor created a set of guiding questions that were visible as students wrote comments about the storyboards. For example, two of the guiding questions asked, What objective was the designer trying to achieve? and What design decisions did the designer make?

Findings

Not surprisingly, students identified several benefits to engaging in peer critique, whether it was online or face-to-face. Interview data revealed that students valued the activity of critique for 1) becoming aware of peers' progress through critique, 2) reflecting individually to improve a design, and 3) and getting feedback on designs from peers. However, while students clearly valued *getting* critiqued, the student interviews also revealed mixed attitudes about *giving* critiques to their peers and a surprising range of explanations for their attitudes toward critique.

Rapport among students played a role in students' participation in critiques. Some students expressed that rapport with other students made it easier to engage in critiques. Indeed, this is in line with the instructor s goal of creating a community atmosphere where they [students] can critique each other s work. In interview, she talked about the importance of making people involved in design feel like they can participate. She said, people probably always have something to say, it s just that they don t feel that they can say it. However, the findings also indicate that rapport also was an explanation for withholding certain critical comments from their peers. For example, the attitudes of not wanting to seem "bossy" or not wanting to "give more work" to others by making suggestions to change aspects of a design played roles in how students participated in critique.

A weak sense of shared criteria for critique played a role in students' participation in critiques. Student interviews revealed that a lack of shared concepts of *what to critique* and *how to critique* inhibited students' ability to participate in critiques. One student expressed the need to have shared conceptions of what to look for. In this quotation, reveals this sentiment:

> sometimes that structure, that lack of structure it does make it difficult. And I think anything that could ve helped that along would have been nice. Specific questions that deal with specific issues of the software, you know more guiding questions or something, so people will be talking about things and kind of be referring to the same things.

It was expected that students would be eager to bring their expertise to a critique; however, another student in the class revealed a resistance to giving feedback about an area in which she has some extra expertise. Because she saw others in the class as *not* having that same expertise, she *held back* from making critiques related to those issues. She said,

> As a group we haven t talked about what those elements are in terms of design. So it s very hard to criticize them [other students] I don t talk about that, so they wouldn t so I just don t comment on that sort of stuff, because I don t know how, except within our group. Cause I can take the time to explain grids for example.

Like those students who may be withholding certain suggestions, she is concerned about people responding negatively to her feedback. Moreover, her behavior is also related to perceptions of the groups shared set of criteria for critique. She perceives her expertise as falling outside a shared framework for evaluating design, and therefore feels uncomfortable bringing it to a critique.

Online critiques did not meet students' expectations; they were "too nice." Though students found critique to be very valuable for them in general, many students were unsatisfied with the responses their group received in Studio Zone. Students thought the responses online were too nice or not critical enough. Not only did students seem to want a different *level* of feedback, they seemed to want *more* of it. The following interview excerpts (with my emphasis added) exemplify these sentiments about the online postings:

> I put what I wanted to put, in a nice way. But I still made it clear, **but I thought some people kinda skipped over somethings. They really didn t give the feedback that maybe could ve**

> **helped.** Or, they didn t do, like we counted comments to be honest. Five people .we re like, ok, where are they? You know, and where was their feedback?
>
> **there were some critical things that came out, that were good to hear, but I think this was the first time people had done it. People were really nice.** [laughs] And very positive and at that point in the design, I think it was a good thing **because we had no idea about where we were at** and they gave some good feedback. But a lot of it was more, this is good, or you know, this looks fine. Cause maybe they didn t have a really great idea of what was expected as far as like how intense and how deep to go. And I know there were questions guiding that, and I think people took that. But it was just the level of where their comments went. It was fairly superficial.

The ability to structure critiques was perceived as a strength of Studio Zone. For one student, her beliefs about how design is learned and should be taught seem to have a lot to do with *breaking things down* and *providing structure*. Thus, she sees Studio Zone as a place to create that structure and break things down.

> I think the good things about Studio Zone is they are actually giving us a place and a framework for talking about design. Not much in that class is structured and it s really refreshing that Studio Zone be there for providing some structure.

This student seemed to be responding the fact that Studio Zone can structure critiques by organizing presentation and response to work. One particular way of structuring critiques that students seemed to find useful was Studio Zone s guiding questions.

> [Guiding questions] are a real plus cause then everybody has the same set of questions. You know we do it in class, you don t always pose the same questions for every single one, because it just becomes redundant with the whole group.
>
> that s where those guiding questions are really good. You know whenever you teach something like this you have to break it down into its pieces.

Though students reported that guiding questions were useful, it is not clear how students actually used them to construct their responses. For example, though the questions appeared every time a student composed their comment, data was not collected to determine whether or not students read through all the guiding questions, or the extent to which they relied of the questions.

Asynchronous interaction was perceived as an advantage to online critique. The fact that communication through Studio Zone is asynchronous and allows users time to study and compose a critique seemed to be valuable to students. These interview excerpts shows how this feature is aligned with the concern to give thoughtful feedback:

> I felt really comfortable to say things and just **it gives you time** . Like maybe you want to say something, but doing it online gave you the opportunity to think about how to say, without maybe hurting someone s feelings. Whereas you might in a one-on-one or group setting, just blurt something out without maybe even thinking to consider that person s feelings, cause there s just not enough time, and they do want your feedback.

The instructor viewed Studio Zone as valuable for extending opportunities for critiques since she viewed it as too time consuming to do it [with every group] in class. Though being able to analyze and critique design was a high priority goal for her students, she preferred to use class time for group work.

The limited dialogue structure was perceived as a weakness of Studio Zone. The rather rigid dialogue structure was viewed as limiting. The structure of critiques online allowed for the presenter to post an image representing the design and some text describing it. Other students could then post comment notes in response. Studio Zone did not allow for the presenter to easily respond to critiques or questions a student may have raised in a comment note. Hence, the structure and timing of interaction seems to be a key contrasting element between face-to-face and online critique sessions. While allowing students to comment on designs at their own pace was seen as an advantage to using Studio Zone, the drawback was that the students being critiqued could not respond immediately. This was seen as especially important if students felt the need to clarify or justify in defense of their design rationale.

Responding to all projects was viewed as too time consuming. Another problematic aspect of Studio Zone students identified was the time demand required to respond to projects. While students described the

guiding questions as useful as they tried to critique a design, they found it difficult to consider all of the guiding questions for each of the designs posted. In total, there were 20 pages of designs posted on Studio Zone. Thus, making detailed comments to each of these would have required a significant amount of time.

The visual orientation of Studio Zone encouraged responses to interface instead of conceptual issues. The instructor attempted to guide the online critiques toward discussion of the conceptual aspects of students designs. Students suggested that the structure of Studio Zone lent itself well to critiques focusing on aspects that are more visual in nature rather than conceptual. The following quotation reflects this issue:

> you don t get an idea of the project, you just get an idea of the screen. And if we had looked at it as a whole project I think that that would have helped give it more meaning at that stage.

For the particular stage students were in during the time of the online critique, Studio Zone s emphasis on the presentation of designs in visual form did not neatly fit the kind of presentation they needed to make. Some students voiced the frustration that visual orientation put undue emphasis on visual aspects when the overall task design and learning goals should have been the focus of the critique.

Discussion

The findings presented here suggest that developing technology for online critique is warranted. Indeed, as an activity construct, critiques (whether face-to-face or online) were viewed as valuable for learning to design for the social and cognitive functions they served for class participants. These educational benefits probably explain why the instructor valued the activity so much as to extend opportunities for critique with the help of asynchronous technology.

Students perceptions of the benefits of critique revealed in this study were not very surprising given that the design crit is a staple of pedagogical approaches in design fields like architecture and graphic design. However, this study also uncovered some factors that seem to influence the potential to learn through critiques. These played out in students' perceptions of online critique. Specifically, rapport among students and not having shared criteria for "good critique" shaped how students participated online.

What are the implications of the lack of shared frameworks for how students perceived feedback they *received*? The lack of shared norms can explain why students were dissatisfied with the kind of comments they received from others. Nice comments were perceived as insufficient because they did not hit on the issues that needed addressing. Students were also unsatisfied with the levels of participation on Studio Zone. Given the value students held for getting critical responses, this was likely disappointing for students.

What are the implications of the lack of shared frameworks for how students *gave* critiques? Perhaps the weak sense of good critique also discouraged students from feeling comfortable taking the role of the more knowledgeable other in a critique. The findings revealed instances in which students withheld potentially useful feedback due to a sense of rapport with peers and their perceptions of the lack of shared criteria. It is interesting that while students consistently talked about critiques as valuable for *receiving* critical responses from peers, they did not explicitly seem to value them for *giving* feedback to others. Since students expressed a sense of concern for and rapport with their peers, it doesn t seem likely that students didn t want to help their peers by giving good critiques. Instead, the more probable explanation is that they just did not know how to go about it.

This finding is especially problematic since the success of peer critique depends on students feeling comfortable as the critiquer. Seen through Vygotsky s notion of ZPD, students were in effect *declining* the position at the *top* of a zone of proximal development. For students to benefit from each other s expertise, they must know how to share their knowledge in a socially acceptable way. Hence, even when a zone of proximal development is theoretically created in a critique, there is no assurance that the learning potential will be realized unless these social aspects are taken into consideration.

Of course, the points of students dissatisfaction with online feedback and the lack of shared criteria for critique should not overshadow the perceived benefits of critiquing online. The ability to structure and guide the focus of the critiquing activity with guiding questions was seen as useful. And, being able to take time to construct critical comments also seemed to be an important advantage to online critique. Weaknesses of the Studio Zone design identified by students pointed to areas that could be refined to better support and enhance the advantages of online critique. The single level *post-response* structure of the critique was seen as inadequate for the kind of dialogue students needed. And, while guiding questions were generally helpful, students could not have reasonably thought about each one for every design posted. Consequently, the visually oriented presentation of designs may have made it easier to respond to visual features rather than the conceptual ones, as suggested by the guiding questions. It seemed that students believed in the potential for Studio Zone as a place for holding critiques, while also voicing reasons why

the particular online critique they participated in did not fully meet that potential.

Implications

The findings reported in this study have implications for the design of technology tools for critiques and how instructors use them. One major implication is that students should be encouraged to build and negotiate shared norms to guide their practice of critique. The instructor should be cognizant of the need for shared criteria and could explicitly engage in discussion about the ways and purposes of critiquing. Expectations for what the content of presentations and responses should be discussed. Shared norms could also be established by providing interaction with experts who can model ways of critiquing and sharing expertise. Web-based technology makes it easier to interact with experts asynchronously and over distances. It seems that a key to maximizing the learning potential through critiques is not to enforce a singular way of critiquing, but to match expectations among participants in a critique. Thus, these expectations should be made explicit whenever possible.

Another implication is that students should be encouraged to be aware of their own critiquing styles and skills. One reason to encourage this is that it may be beneficial for students to understand their own strengths and weaknesses in terms of areas of expertise. They should feel comfortable and be eager to share their expertise in critique when appropriate, but also they should acknowledge when another s expertise could help an area where the student might be weak. This might encourage students to seek help and learn from others while also inspiring confidence in their own strengths. For giving feedback, they should be sensitive to the manner in which critique peers. They should be encouraged to give rationales for their opinions, even for giving praises. Giving positive feedback can be especially constructive if the reasons for that praise are given. When receiving feedback, they should be alert to taking critiques personally. It would also be useful to have a personal policy of when to accept suggestions and when to disregard them. This might also encourage students to give suggestions without feeling they are forcing the other to change their design.

This study also suggests some specific implications for how an instructor should structure the use of Studio Zone. First, the instructor should set expectations for the class about the role Studio Zone is meant play in the course. Students and the instructor should have a clear idea about the purposes of online critiques in relation to face-to-face critiques. There should also be concrete expectations for participation in terms of how often students present work and how much they respond to work. Second, the structure of activity should help focus critiques in ways that are appropriate to what is being critiqued. This could involve making sure the focus of critique is not too broad by allowing a limited number of designs to be posted. Fewer guiding questions might also encourage a deeper level of response since students would not have to analyze and comment on a large number of designs. If the focus of the critique is more conceptual, rather than visual (as was the case in this study), the manner of presentation should account for that. One way to do this is to ask students to post conceptual diagrams. Students should also be encouraged to articulate the kind of feedback they would like to receive given their current stage in a project.

For the design of Studio Zone, the findings of this study suggest that web-based technology offers advantages for critique. However, particular features such as guiding questions, the structure of dialogue, and modes of presentation need to work in tandem with the criteria and expectations developed by the instructor and by the students. For example, setting the expectation that students give deep and focused critiques must be matched with software features and structures that allow them to do so. One way to do this might be to rigidly structure students responses by providing separate text boxes in which students must respond to a specific guiding question. A possible software feature would allow the response structure to be eventually relaxed so that students are not bound by specific instructions. Another possibility is to design a way for students to build the shared norms and criteria for critique by allowing them to collectively build the sets of guiding questions for critiques. Further research is needed to determine ways of configuring guiding questions and designing dialogue structure that best suit the needs of critique.

Conclusion

This study lends support to the idea that a web-based technology tool like Studio Zone can help students learn from design critiques. As expected, it was found that there are important social and contextual aspects of design critiques that need to be considered in the design of a technology tool to support critique. Specifically, perceptions of shared norms and criteria for critique and the structure of Studio Zone were identified as especially important factors in shaping how students participated in critiques.

Technically, allowing students multiple ways to present information and communicate online is relatively easy. What is more of a challenge is to leverage the technology to foster positive habits and skills that are needed to support a community of student designers. This study begins to shed some light on how to craft both the technology tools and the social context of the educational environment to optimize students' ability to learn through design critiques.

References

Bell, P., Davis, E.A., & Linn, M.C. (1995). The knowledge integration environment: Theory and design. In J.L. Schnase & E.L. Cunnius (Ed.), *Proceedings of the Computer Supported Collaborative Learning Conference, CSCL '95, Bloomington, IN* (pp. 14-21). Mahwah, NJ: Lawrence Erlbaum Associates.

Collins, A., Seely Brown, J., & Newman, S. E. (1989). Cognitive Apprenticeship: Teaching the Crafts of Reading, Writing, and Mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 453-494). Hillsdale, NJ: Lawrence Erlbaum Associates.

De Young. L. (1996). Organizational Support for Software Design. In T. Winograd (Ed.), *Bringing Design to Software* (pp. 253-267). New York, NY: ACM Press.

Gal, S. (1996). Footholds for Design. In T. Winograd (Ed.), *Bringing Design to Software* (pp. 253-267). New York, NY: ACM Press.

Kafai, Y. (1995). *Minds in Play. Computer game design as a context for children's learning.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Kolodner, J. and K. Nagel (1999). The Design Discussion Area: A Collaborative Learning Tool in Support of Learning from Problem-Solving and Design Activities. *Proceedings of CSCL '99.*

Kydd, S., Dyke, A., & Jenkins, D. (1999*). Hypermedia Version Support for the Online Design Journal*. Retrieved April 21 from the World Wide Web: http://cd-pub.bu. edu/students/grads/dgd/workshop/kydd.html

Lee, Y., Kerner, N., & Berger, C. (1998). Student perceptions of their progress using computer-assisted collaborative inquiry in the laboratory, National Association for Research in Science Teaching: San Diego.

Linn, M.C. (1995). Designing computer learning environments for engineering and computer science: The scaffolded knowledge integration framework. *Journal of Science Education and Technology*, 4(2), 103-126.

Loh, B., Radinsky, J., Russell, E., Gomez, L.M., Reiser, B.J., & Edelson, D.C. (1998). The Progress Portfolio: Designing Reflective Tools for a Classroom context. In *Proceedings of CHI 98*. Los Angeles, CA: ACM Press.

Puntambekar, S. & Kolodner, J. L. (1998). The design diary: development of a tool to support students learn science by design. In *Proceedings of The Third International Conference on the Learning Sciences*, Atlanta, Georgia: AACE.

Rowland, G., Fixl, A., & Yung, K. (1992). Educating the Reflective Designer. *Educational Technology*, 32(12), 36-44.

Scardamalia, M., & Bereiter, C. (1991). Higher levels of agency for children in knowledge building: A challenge for the design of new knowledge media. *Journal of the Learning Sciences*, 1(1), 37-68.

Schon, D. A. (1985*). The Design Studio: An exploration of its traditions and potentials*. London: RIBA Publications.

Schon, D. A. (1987*). Educating the Reflective Practitioner*. San Francisco: Jossey-Bass Publishers.

Shabo, A., Guzdial, M., & Stasko, J. (1999*). An Apprenticeship-Based Multimedia Courseware for Computer Graphics Studies Provided on the World Wide Web*. Retrieved Mark 18, 1999 from the World Wide Web: http://guzdial.cc.gatech.edu/papers/cd-graphica/.

Shaffer, D. W. (1999). *The design studio as a model for education*. Retrieved September 15, 1999 from the World Wide Web: http://dws.www.media.mit.edu/people/dws/papers/designstudio/index.html.

Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.