

# **"It's not just programming:" Reflection and the Nature of Experience in Learning Through Design**

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**Abstract:** When students with varying levels of expertise collaborate on computer-based design projects, different roles for experienced and inexperienced designers often emerge. The goal of this study was to determine if students with different levels of experience, knowledge, and skill in learning through design are aware of these differences; and also if they are aware of how this variation affects their collaborative interactions. Toward this end, sixty-two fourth and fifth-grade designers with varying levels of expertise in design and programming were interviewed following their participation in a 10-week learning through design project. Students were asked to identify differences between experienced and inexperienced designers. Their responses were classified via an emergent coding scheme. Results showed that students were aware of differences not only in requisite skills, but also how these skills contributed to collaborative interactions. Students cited knowledge and interaction differences in relation to visible skills like programming more often than other meta-design skills, such as planning and project monitoring.

**Keywords:** learning through design, discourse analysis, assessment of learning

## **Introduction**

Researchers in CSCL are currently striving to document the effectiveness of technology-infused curricular interventions such as project-based learning, learning through design, inquiry-based learning, and a whole host of other models for meaningful reform in mathematics and science education. Evaluations of such curricula have focused on content mastery in mathematics, science, or engineering (e.g., Brown, 1991; Kolodner, 1998; Roth, 1998); technology skill acquisition (e.g., Harel, 1991; Kafai, 1995; Lehrer, 1992); students' self-monitoring and project management (Carver, et. al., 1992; Marshall & Kafai, 1998); and student interest and motivation (e.g., Fredricks & Blumenfeld, 1997). In all four of these areas, research has yielded encouraging results. Several questions still remain, however; one of these is the extent to which students themselves are aware of developments in their knowledge and skills after experiencing these kinds of projects. Another question takes this notion of self-awareness one step further and asks: if students do realize their own experiential gains, how reflective are they about the ways this prior experience affects their subsequent performance and collaborations in similar

projects? This study represents a preliminary attempt to address these questions through an analysis of interviews with students in a learning through design project.

In learning through design, as distinct from project-based or problem-based learning, students develop deep understanding of academic content by creating meaningful products that reflect their knowledge of subjects such as mathematics (Hall & Stevens, 1995; Harel, 1991; Kafai, 1995), science (Hoadley & Cuthbert, 1998; Kafai, Ching, & Marshall, 1997; Kolodner, et. al., 1996), engineering (Roth, 1995), and social sciences (Lehrer, 1992; Ianodou, Reppening, & Zola, 1998; Yarnall & Kafai, 1997). These projects require that students not only learn the subject matter well enough to represent it in a final design, but also that they master the particular means of production used to create the product itself. Production means can include physical model-making, scale-model drawing, or the creation of software via programming and/or multimedia authoring. Acquiring these concrete design skills is therefore a crucial part of the learning gains that students make in such projects.

Students experiencing learning through design come away with more than academic knowledge and model-building or computer skills, however. Another set of skills, less tangible and more difficult to document, plays a crucial role in students' success in learning through design. These skills emerge from practices in which students plan, manage, monitor, revise, and reflect on their emerging products (Blumenfeld, et. al., 1991). Such meta-practices have been included in the overall notion of the nature of design experience as discussed by researchers (e.g., Carver, et. al., 1992; Roth, 1998; Schon, 1986); however, systematic efforts to document actual gains in these skills have been rare (c.f., Marshall, 1998).

A question for this research was whether or not students themselves are aware of their own developing skills and understandings in regard to fluency in the means of production for their design (i.e., programming and multimedia authoring) and design meta-practices (i.e., reflective planning and design monitoring). A related study on students' "mindful practices" in learning through designing software found that when asked to talk about their competencies with programming and planning, students were able to engage in fairly sophisticated discussions about these topics (Kafai, under revision). Additionally, research demonstrates that both structured activities and clinical interviews designed to support students' reflections on abstract, metacognitive properties of their science learning experience can affect students' content learning (Ackerman, 1995; White & Frederiksen, 1998). In the current study, rather than prompting students to talk or write about specific issues, I wanted to find out what skills and practices they would spontaneously mention when considering the nature of experience in learning through design. The focus here is not only on how students conceive of design "experience" as a property of individuals, but also their awareness of how this experience comes into play in their design collaborations with others. Lave emphasizes the importance of attempting to "locate learning throughout the relations of persons in activity in the world," (Lave, 1993, p. 27). It is this directive that influenced the choice here to ask students to reflect, not about skills or competencies in the abstract, but on the different ways of knowing and

doing exhibited by individuals with varying amounts of design expertise as they worked in the design project.

As an example of how this type of reflective awareness might look, consider the following case. Brian, a fifth grade student (all names have been changed), contributed to the title of this paper. During fall of 1998, he and sixty-three other fourth- and fifth-graders participated in a research project examining apprenticeships among students with varying levels of experience in learning through design (Ching, 1999). The students' task was to design and program simulations about marine biology in collaborative teams. In Brian's classroom, teams contained fifth-graders with prior design experience and fourth-graders with no design experience. When asked in the final interview if there were any differences between how fourth- and fifth-graders worked on the simulation design project, Brian replied:

Brian: Well, we [5<sup>th</sup> graders] have experience, so sometimes we help them [4<sup>th</sup>] with the simulations.

Researcher: How do you mean? With programming?

Brian: Yeah, (pause) but it's not just programming, because Melody [a 4<sup>th</sup> grader] pretty good at that. But, like, if I see something that's not planned well, or maybe over-scheduling, then I'll say something about that.

In his answer Brian asserts that the difference between students with and without experience in learning through design is that experienced students sometimes help the inexperienced ones create their collaborative simulations. This is not surprising. His subsequent response to the interviewer's prompt, however, demonstrates that this "help" does not consist solely of programming assistance, but also help with design plans and time management. Brian's conception of "hav[ing] experience" is thus more complex than technology skill acquisition or knowledge about a particular science topic. But how representative is Brian's answer of his entire cohort of sixty-three students? Are all student software designers as aware of their own skills in addition to programming, and how do they conceptualize the effects these skills have on their collaborations with others?

In this study it was hypothesized that students with previous design experience would be able to draw on their own experiences as newcomers to design when they were asked to consider the design experience from the perspective of their inexperienced collaborators. Additionally students who collaborated with others having significantly more or less design experience than themselves were expected to report the most differences in computer-specific skills such as programming. It was expected that they would also report differences in meta-practices such as design monitoring and planning, as in Brian's example above. Students who collaborated with others having only a minimal difference in design experience from themselves were expected to notice these variations less and thus report fewer distinctions in skills and meta-practices. Our findings yielded that students with previous experience were indeed more facile with perspective shifting.

Interestingly though, while the results suggest that experience variations in meta-skills contribute to students' perceptions of overall differences between novice and expert designers, students rarely mention differences in meta-skills specifically, particularly in comparison to their prolific citing of programming and computer skills.

## Methods

During fall of 1998, two classes of fourth and fifth-grade students participated in a learning through design project in which they learned marine biology and designed collaborative software simulations about that topic for a ten-week unit. Both science classes were taught by the same teacher. In the focus classroom, all fifth-graders ( $n = 17$ ) had participated with our research team in a design project during the previous year as fourth-graders, when they learned neuroscience (see Kafai & Ching, 1998; Marshall & Kafai, 1998). These students-"oldtimers"-thus had experience in all the facets of our version of learning through design: integrating learned science content with design, planning and monitoring in collaborative teams, and programming with Logo Microworlds. All of the focus fourth-graders-"newcomers"-were new to learning through design ( $n = 16$ ), and all but one had not learned Logo programming previously. In the comparison classroom, all of the fifth grade students ( $n = 15$ ) had learned a minimal amount of programming during 1997, but none of them had participated in a full-scale design project before. As in the focus class, none of the comparison class fourth grade students had experienced design previously either ( $n = 15$ ).

Collaborative teams of between three and five students each were created in both classes, with experienced and inexperienced students distributed equally across groups. This composition of students across classrooms and teams is ideal for examining students' conceptions of themselves and others as designers, in that students with more experience in various facets of design regularly collaborate with inexperienced students to create their simulations. Students thus have ample opportunities to observe the ways in which prior knowledge and skills affect not only individual experience but collaborative patterns as well. The question is whether or not students will reflect on these issues when asked to talk about the nature of design experience.

The data for this study comes from a set of post-interviews conducted with all sixty-three students in both classrooms. One student's interview was left out of analysis due to faulty sound recording (a female newcomer) for a total of 62 interviews. All interviews were videotaped. During the post-interviews students answered questions about multiple aspects of the design project. This study focuses only the last three questions, which dealt with student impressions of differences between fourth- and fifth-graders. Specifically, students were asked the following questions:

1. Can you think of any differences between 4<sup>th</sup> and 5<sup>th</sup> graders in terms of how they worked on the simulation design project? What are they?
2. What does it mean to be a 4<sup>th</sup> grader working on this simulation design project?
3. What does it mean to be a 5<sup>th</sup> grader working on this simulation design project?

All students were asked all three questions, such that students had opportunities to reflect on their own situation as well as that of students in the other grade level. Oldtimers are distinct, however, in that when answering the second question they can draw on their own experiences as a newcomer to design during the previous year, in addition to reflecting on the perspective of fourth-graders in the current project.

The portions of student interviews containing these last three questions were all transcribed completely. A subset of the interviews was used to create an emergent coding scheme for the qualities that students spontaneously mentioned which distinguished experienced and inexperienced designers. It became obvious while creating the scheme that students' discussions of the nature of design experience were not limited to the confines of particular questions. The three questions together elicited a comprehensive range of answers, but each question did not seem to capture a unique aspect of students' reflections. For this reason, the entire interview segment containing student responses to all three questions was coded thematically, rather than coding each question separately. Each utterance that raised a particular theme was coded; therefore, students could mention several types of differences between fourth and fifth graders and have their variety of responses captured by the scheme.

The three main qualities students in the scheme-creation subset named as distinguishing experienced students from inexperienced students were as follows: (a) knowledge differences, (c) affective differences, and (d) differences in social roles within collaborative groups. There was also a fourth code for (e) no difference. Some of these umbrella codes were broken down further to represent more detail; this will be discussed in the following section. After the scheme was determined, the interviews used for creating the scheme were randomly dispersed throughout the rest of the data set, and all interviews were coded by two separate coders. Twenty percent of the interviews were coded for inter-rater reliability by both coders, and the results yielded that raters had reliable agreement ( $\alpha = .9276$ ).

## **Results**

Students in both classrooms seemed fairly aware of the effects that previous knowledge and skills had on the personal experiences of individuals in the design project and also on collaborations within teams. There were interesting differences in several areas between oldtimers and newcomers, and between the focus and comparison classes. Reporting of results has been broken down into: the emergence of categories and subcategories in student responses, breadth of characteristic awareness, differences in affect and reported knowledge, and differences in reported social roles. Each will be discussed in turn.

### **Emergent codes for types of difference**

As cited above, the main codes that emerged from student responses were affective differences, knowledge differences, and social role differences. There was also a fourth code for "no difference." The descriptions students gave of knowledge and social role differences were more multifaceted than could be captured by a single code, however. In

terms of knowledge differences, the different types of knowledge students cited were as follows: (a) general or unspecified knowledge [e.g., *"fifth-graders seemed to know more"*], (b) knowledge about programming specifically [e.g., *"they were newer to Microworlds than us"*], and (c) knowledge about specific aspects of design other than programming [e.g., *"fourth-graders didn't know how to spread out the work"*]. The social roles code refers to differences students mention in regard to how fourth- and fifth-grade students interacted with each other. Most often students phrased this difference in terms of giving or receiving help with some aspect of project work. As with knowledge differences, the picture painted by students was more complex than the initial category. They cited the following types of social roles: (a) general or unspecified giving and receiving help [e.g., *"we had to help the fourth-graders to know what to do"*], (b) giving or receiving help with programming [e.g., *"you could always ask a fifth-grader if your animation wouldn't work"*], and (c) giving or receiving help with other specific aspects of design [e.g., *"fourth-graders couldn't make the schedule by themselves"*]. Together with the single code of affective difference, these sub-codes for knowledge and social role differences make up seven types of observations students spontaneously cited as distinguishing fourth and fifth grade designers. That students could spontaneously discuss differences in such a complex and sophisticated manner supports the argument that design provides students a rich context in which to learn and interact with tools, artifacts, and with each other.

#### **Breadth of characteristic awareness**

In order to assess the breadth of characteristic differences students cited between fourth and fifth-grade designers, each student's entire set of responses for all three interview questions was examined as the unit of analysis. Student interviews were analyzed for the total number of difference types students mentioned. For example, a newcomer who mentioned receiving help with programming, fifth graders knowing more, and it feeling harder as a fourth grader would receive a total score of 3. Oldtimers spontaneously generated more types of difference ( $M = 4.000$ ,  $SD = 1.368$ ) than newcomers ( $M = 2.800$ ,  $SD = 1.082$ ), comparison fifth-graders ( $M = 2.933$ ,  $SD = 1.387$ ), or comparison fourth-graders ( $M = 3.200$ ,  $SD = 1.265$ ). Analysis of variance revealed that oldtimers' breadth of citations was significantly greater than that of any other group ( $MS = 4.713$ ,  $F = 2.855$ ,  $p < .05$ ).

While breadth of awareness demonstrates students' understanding of design's complexity, occasionally students did in fact cite no differences at all between fourth and fifth grade designers at some point. Most of these students either contradicted themselves later or explicitly changed their minds in response to a subsequent question in the interview; thus it is tempting to throw out the "no difference" responses. Capturing these utterances, however, yields some insight into how salient such differences were, that students would even consider "no difference" as an answer. The proportion of comparison fifth-graders reporting "no difference" at some point (60.0%) was much larger than that of any other group (see table 1). This result suggests that these fifth-graders did not perceive that their previous programming experience represented a significant difference between themselves and their fourth-grade counterparts. Since both fourth and fifth-graders in the comparison class had never experienced full-scale design before, this result supports the

argument that skills other than programming play an important role in constituting design expertise.

Table 1. Perceived differences by class and grade level.

	None	<i>Knowledge Differences</i>			<i>Affective Differences</i>	<i>Social Role Differences</i>		
		General	Program	Meta-skills		General	Program	Meta-skills
Focus Class Newcomers (17)	35.3%	18.8%	31.3%	0.0%	20.0%	18.8%	15.6%	0.0%
Oldtimers (15)	20.0%	37.5%	34.4%	0.0%	41.2%	28.1%	28.1%	13.0%
Comparison Class 4 <sup>th</sup> grade (15)	26.6%	30.0%	26.7%	16.6%	26.0%	26.6%	20.0%	0.0%
5 <sup>th</sup> grade (15)	60.0%	36.6%	16.6%	0.0%	33.0%	23.3%	23.3%	0.0%

#### Differences in affect and reported knowledge

One area in which there were notable differences between grade levels in the focus class--between students with prior design experience and those without--was in terms of mentioning affective differences. Focus fifth-graders cited differences in "how it feels" to be a fifth-grader versus fourth-grader in the design project over twice as often (41.2%) as fourth-graders did (20.0%). This result suggests that affective differences may be more salient to oldtimers, because they can draw on their own experiences as fourth-grade designers in the previous year for their reflections. Indeed, after examining oldtimers' responses a second time, it appears that many of them did compare their own experiences during the two consecutive years. Consider the following example:

Researcher: What does it mean to be a fourth-grader working on this simulation design project?

Lena: Well, I remember you feel kinda stupid at first. Like, you don't know what to do.

Researcher: And then what does it mean to be a fifth-grader working on this simulation design project?

Lena: You feel more in control, I think. You can tell what's gonna happen next.

In contrast to the focus class, comparison fifth-graders (33%) and fourth-graders (26%) had similar estimations of affective differences between experienced and inexperienced students in their classroom. Comparison fifth-graders also rarely talked about their own experiences learning programming the year before in reflecting on the perspective of fourth-graders in the design project. A possible explanation for this result is that because fifth-graders' prior knowledge was skill-based rather than practice-based, it was therefore not as comparable to the current design project.

In discussing skills or knowledge-based differences between experienced and inexperienced designers, students in both classrooms were fairly similar in their impressions. Interesting differences arose from this analysis, both between classrooms and in the total population among sub-codes. Students in both classes cited differences in general knowledge and programming knowledge relatively frequently. Differences in knowledge about specific design skills or practices other than programming, however, were cited very infrequently by comparison. Interestingly, the only group of students to mention differences in knowledge of meta-practices was fourth-graders in the Novice Class (16.6%). This result is somewhat surprising, in that the specific design skills and practices other than programming are precisely those things that distinguished oldtimers from newcomers. One might expect that these differences would be cited more often, at least among oldtimers.

### **Differences in social roles**

In the focus class, differences in programming roles were cited by a much larger percentage of oldtimers (28.1%) than newcomers (15.6%). A similar pattern to that of knowledge differences emerged across categories in the total population. Differences in general social roles and social roles related to programming help were cited by a large proportion of all students. Again, differences in social roles related to help with meta-design skills or practices were rarely mentioned. In contrast to knowledge differences, however, here in their discussions of social role differences, the only students to cite differences in help giving or receiving in meta-practices were oldtimers (13.0%). This result is more in line with what was expected, but it is puzzling why meta-practices were not cited more often.

### **Discussion**

The goal of this study was to determine if students in a learning through design project were aware of significant differences between experienced and inexperienced designers, in regard to their individual experiences and knowledge, and also how that experience or lack thereof affects interactions with others. The results suggest that students are aware of these differences and can talk about them in multiple ways: in affective terms, in terms of individual knowledge, and in terms of resulting social roles. Oldtimers seemed to have more of a multifaceted understanding of the various ways in which design experience affects collaborative interactions, as evidenced by their receiving significantly more difference codes. Furthermore, prior participation in a complete design project seemed to make much more of an impression on students about experience differences than prior programming knowledge, as seen by the much larger proportion of students in the focus class who said that there were differences between fourth- and fifth-graders. Students with this prior design experience were also able to talk more about affective differences and perspective-taking due to recalling their own feelings during the previous year.

While these are encouraging results, other findings of this study raise still more questions. Why were there no notable differences between focus class and comparison class students on their impressions of experience-based knowledge and social role distinctions? One would expect that the distinction between prior design experience and



prior programming knowledge would have more of an effect on these areas. Further, why did most students virtually ignore the planning, monitoring, and facilitation aspects of design in their discussions of knowledge and social role differences? Following is an attempt to provide possible answers for these questions.

One possible explanation for both the questions raised above stems from the issue of what knowledge and skills are most valued by students. Previous research demonstrates that computer use and skills tend to be highly valued by students in technology-infused classrooms more so than other practices which also contribute to project-based work (Ching, Kafai, & Marshall, 1998; Kinnear, 1995). Thus it could be that students notice these differences more in practice due to their status value, which explains why they specifically mention programming more than other design skills in the interviews. Alternatively, students may take note of the differences in other design skills, but do not mention them to interviewers. Perhaps students lump these planning and monitoring skills in with "general" knowledge or help in their discussions but point out only programming specifically. Since fifth-graders in both classrooms had prior programming knowledge, differences in prior experience with other design practices may have been overshadowed by the higher status valence of programming skill.

A different explanation for students' neglect of planning, monitoring, and revising skills in their discussions deals with the visibility of such practices in the design environment. These activities are strongly situated within the design project itself and its interconnected practices; consequently, they may be difficult for students to think about in abstract terms on a continuum of skill. Lave and Wenger argue that in communities of practice, the breakdown of practice-specific activity into component "skills" is an artificial construct imposed on the community by researchers and evaluators. In everyday activity, the authors claim, such abstract "theories of practice" have little relevance to conceptions of learning and doing in these communities (Lave & Wenger, 1991). Thus it could be that students in design projects, when prompted to talk specifically about their "skills" in planning and revising designs, are able to make these "artificial" distinctions. When they spontaneously generate characteristic identifiers of experienced and inexperienced designers, however, these distinctions in meta-design skills remain bound to specific practices and are not seen as abstract properties of individuals.

This study has demonstrated that students can reflect on the nature of experience in design projects in multiple ways. This research, along with other interview studies of students in design (Kafai, under review) and other project-based environments (Roth, 1998), contributes toward our understandings of what kinds of skills, knowledge, and experiences students obtain from these curricular interventions.

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