Peer Pedagogy: Student Collaboration and Reflection in a Learning-Through-Design Project

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Background: *Existing research suggests that one of the challenges for teachers in persisting with innovative inquiry curricula is their difficulty scaffolding students' transitions into technology-supported and open-ended activities. The question of whether students can effectively scaffold one another's transitions has not been previously investigated, in part, we argue, because of a predominant focus in collaborative learning research on short-term tasks and perfunctory "helping" behaviors.*

Purpose: *This article addresses the nature and role of students' collaborations in learning-through-design, a technology-rich science inquiry curriculum. Within this environment, we examined emergent collaborative patterns among students, the affordances of those patterns for effective learning, and students' reflections on their interactions. We paid particular attention to how students with varying degrees of previous experience in this curricular approach collaborated with one another.*

Setting: *This study took place at a university-affiliated elementary school in a West Coast urban area.*

Population: *Two mixed-grade classes of fourth- and fifth-grade students (n = 63) and their science teacher participated in this study. Fifth-grade students in one class had extensive experiences with learning through design during the previous year.*

Practice: *For 10 weeks during the fall, students in both classes learned about marine biology. During this time, they also worked in teams to create marine simulations using Logo Microworlds programming and multimedia software.*

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Research Design/Data Collection and Analysis: *Design-based research guided the creation of the curriculum and examination of its effectiveness. Ethnographic methods, grounded theory, hermeneutics, and discourse analysis were used to collect and analyze video of student collaborations and interviews. Analysis of variance was conducted using the coded results from student interviews to determine significant differences among groups.*
Results: *We found that experienced fifth-graders took on many socializing functions, effectively apprenticing younger students into the practices of learning-through-design. Interviews revealed that both fourth-grade and fifth-grade students were highly reflective about their respective collaborative roles and that experienced students benefited as much as, if not more so, than inexperienced students from this arrangement.*
Conclusions: *Given experienced students' strategic, effective, and thoughtful ongoing collaborations with their fourth-grade counterparts, we introduce and propose the term peer pedagogy to describe these interactions. This term and our constituent results have implications for existing research and practice with collaborative learning and project-based technology-integrated curricula, as well as for theory and scholarship on children's roles within learning communities.*

Project-based learning is a highly promising kind of learning environment in which students engage in collaborative, technology-integrated, sustained inquiry (Blumenfeld et al., 1991). Yet despite recommendations by standards movements and national organizations (National Council of Teachers of Mathematics, 1989; National Research Council, 1995), this sort of curriculum still represents a significant departure, in practical terms, from the traditional norm for most students. In fact, research reveals that the first project-based unit that students experience is often the most difficult, given students' unfamiliarity with inquiry practices, tools, and ways of thinking (Kolodner, Hmelo, & Narayanan, 1996). This unfamiliarity also represents a significant challenge for teachers. Those who want to implement project-based learning must guide new cohorts of students every year through the rough terrain of building these expectations and understandings. Creating a classroom culture of established norms and preexisting knowledge among students is thus solely the teacher's heavy responsibility in typical situations. In project-based learning, students are often placed in collaborative groups to work together, but students are rarely framed as sharing the teacher's responsibility of instruction and pedagogy.

To demonstrate the possibilities of an alternative approach, this article presents a nontypical situation: a classroom culture of collaborative learning-through-design, a particular type of project-based curriculum wherein fourth- and fifth-grade students perform among themselves many of the socializing and guiding functions for which a teacher is usually responsible. We analyze and describe the interactions among the students, particularly those in which fifth-graders help fourth-graders learn the skills and mindset for computer-based simulation design, and students' perspectives on their own experiences. Our hope is that this work may help shift the discussion toward seeing students, as well as teachers and administrators, as active agents and facilitators of change. All too often, the discussion about classroom reform and technology integration has focused on the institutional level, and even those studies examining teacher efforts have left students out of the equation (Cuban, 1986, 2001; Zhao & Frank, 2003).

Describing the nature of students' collaborative experiences in socializing and guiding one another through the design process is no small matter, however, which brings up the other goals of this article. Systematic studies of collaboration in open-ended, project-based environments are rare (Cohen, 1994), and rarer still are those that not only document student collaborative behavior but also consider students' perspectives on their experiences. This article begins to address these openings in the existing literature through presenting qualitative analysis of video footage of two classrooms' daily learning-through-design collaborations, and mixed-method analyses of videotaped interviews with every student in the project ($n = 63$). Through the combination of these analyses, we argue that experienced fifth-graders in particular demonstrate peer helping that is more strategic, reflective, and effective than that documented in existing literature, and we thus propose the term *peer pedagogy* to describe their activity. We conclude with discussions of our findings for interpreting the roles of children in community participation and classrooms, for teaching and designing project-based learning environments, and for further research on student collaboration in open-ended contexts.

REVIEW OF RESEARCH

The classroom community we worked with and studied was engaged with a particular approach known as learning-through-design. Learning-through-design is part of the larger family of project-based learning and is based on a constructionist model in which students simultaneously learn new information and design a relevant product reflecting their knowledge (Harel, 1991; Harel & Papert, 1990; Kafai, 2005). In learning-through-design, students simultaneously learn science content and use Logo Microworlds object-oriented programming to create educational software products aimed at younger users. Previous efforts in this vein have been situated in mathematics, specifically fractions (Harel; Kafai, 1995), and in several areas of science, including astronomy and neuroscience (Kafai & Ching, 2001; Kafai, Ching, & Marshall, 1997). Existing studies have demonstrated that students engaged in learning-through-design can make significant learning gains compared with matched cohorts of students learning via traditional classroom methods (Harel & Papert, 1990; Kolodner et al., 2003)

Although the project-based family of curricular approaches holds much potential, research reveals that it is sometimes difficult for teachers to adopt or persist in these innovations (Kolodner et al., 2003). In an analysis of teachers' issues in implementing project-based learning, Mintrop (2001) identified some of the problems faced by teachers as creating a fusion of ideological commitment, mastery of the model, clinical tryouts, and reflection that was commensurate with the founders' original implementation. Above all, however, he found that "most often, students turned out to be the strongest obstacle of success when they did not behave according to the expectations of the pedagogy" (p. 233). Other research reveals that teachers and students can become so focused on learning the procedures and mastering the technologies of design projects that they lose track of the scientific content to be learned (Hmelo, Holton, & Kolodner, 2000). Various technology tools and "ramping up" units have been designed by researchers to assist students and teachers with these new ways of thinking and doing (Kolodner & Nagel, 1999; Reiser, 2004). We want to argue here, however, that an alternative means of supporting project-based learning is to create a classroom culture in which experienced students scaffold new students through collaborative learning. In our work, we attend to the collaborative norms and practices that students need to learn in order be engaged in successful inquiry in their classroom.

Student collaboration has been a focus of research on project-based learning for many years. The literature contains analyses of successful and synergistic collaborative designs (Roth, 1995), rich student discussions (Brown & Campione, 1994), gender differences in collaborative tasks (Ching, Kafai, & Marshall, 2000), and long-distance student collaborations via telecommunications (Songer, 1996). Barron (2000, 2003) in particular has recently tackled the critical topic of how student groups begin the inquiry process and collaboratively determine strategies for project-based work. The kind of complex peer-to-peer helping we describe here has not been investigated before, in either project-based research or the traditional collaborative learning literature. We draw on this literature for informing what behaviors we might expect to see, however, in our examination of peer pedagogy in learning through design.

Collaborative learning researchers have evaluated instructional and laboratory situations in which students are assigned strict roles and protocols for working together, as in peer tutoring (King, 1993; Swing & Petersen, 1982). Webb and colleagues have thoroughly investigated the relative impact of interactions during collaborative tasks and concluded that both giving and receiving elaborated explanations lead to greater learning gains (Webb 1980, 1989; Webb, Neimer, Chizhik, & Sugrue, 1998). Another strategy has been to teach all students in teams how to effectively ask for and give constructive help (Webb & Palincsar, 1996). Help-giving and help-receiving has thus certainly received attention in this research; however, the tasks in which students have been involved in these studies are typically short-term problems. Largely, students in traditional collaborative learning tasks give and receive help with obtaining right answers or correct procedures rather than with mastering learning practices for process engagement. Furthermore, most of the existing studies on collaborative learning examine students' interactions within short-term tasks, whereas our work looks at emergent and consistent patterns of interaction over time. In addition to the role of collaborative experience in socializing and guiding one another into learning-through-design, there is the issue of student perspectives. Traditional collaborative learning research rarely queries students' perspectives on their own experiences (cf. King, 1993).

The literature on apprenticeship learning can inform the function of previous experience in students' socializing collaborations, because authors describe members of communities with varying roles and expertise, and occasionally examine children as coparticipants in the contexts under study (e.g., Lave & Wenger, 1991; Rogoff, 1993). Our project represents a significant departure from studies of apprenticeship in formal educational contexts, however. The most prominent educational approach is cognitive apprenticeship as a model for K–12 teaching in academic domains (e.g., Collins, Brown, & Newman, 1989; Scardemalia, Bereiter, & Steinbach, 1984). Some studies in education have opted for placing students in laboratory apprenticeships with practicing scientists (Hay & Barab, 2001; Richmond & Kurth, 1999; Ritchie & Rigano, 1996) or appropriating scientists' tools for use in classroom communities (Edelson, Pea, & Gomez, 1996). In all these efforts, however, there is one constant: Teachers and scientists are always placed in the role of experts, and students are always beginners. At no time are students configured as experienced collaborators in the learning contexts and cultures they inhabit. Within this context, our work on the learning-through-design project also offers a viable alternative to the apprenticeship models that have been the staple of most educational implementations.

Our work focuses on children as both beginners and experts collaborating in the learning through design project. This study examines multiple aspects of children's collaboration in project-based learning: how they work with inexperienced peers, how they carry and convey norms and practices of learning through design through these interactions, and how students' reflections on their own collaborations and experiences contribute to the classroom learning culture.

CONTEXT AND METHODS

PARTICIPANTS

Two classes of fourth- and fifth-grade students located at a university-affiliated elementary school in a West Coast urban area participated in this study. The same teacher, using the same curriculum activities, taught both classes. The focus classroom contained 33 students: 16 fifth-graders and 17 fourth-graders. All the focus fifth-grade boys ($n = 9$) and girls ($n = 8$) participated in a software design project on the brain during the previous year. The 15 focus fourth-grade boys ($n = 9$) and girls ($n = 7$), on the other hand, had no previous experience with long-term inquiry in learning-through-design. The comparison classroom contained 30 students: 15 fifth-grade boys ($n = 8$) and girls ($n = 7$) and 15 fourth-grade boys ($n = 10$) and girls ($n = 5$). The main difference between the focus and comparison classrooms is that none of the comparison students had previous experience with learning-through-design. Comparison fifth-graders had, however, approximately 3 weeks of exposure to the programming environment used in this study during the previous year. (This distinction between the fifth graders in both classes in terms of previous participation in the culture of learning-through-design versus limited technical knowledge becomes crucial later on.) Ethnic breakdown of the children in both classes was as follows: 30 Caucasian, 14 Latino/Latina, 8 African American, 6 Asian, and 5 mixed ethnicity. We selected these two classes for our study because they had the same science teacher; she had worked with us on previous design projects.

The focus class had nine mixed-gender teams, and each included at least 2 experienced fifth-graders and 2–3 inexperienced fourth-graders; the comparison class has also nine mixed-gender and mixed-grade teams with similar distributions. The teacher and researchers decided on the composition of teams for each class according to principles of best practice: ensuring a balance of gender and experience among team members as well as attempting to avoid known student personality clashes within teams.

CLASSROOM SETTING

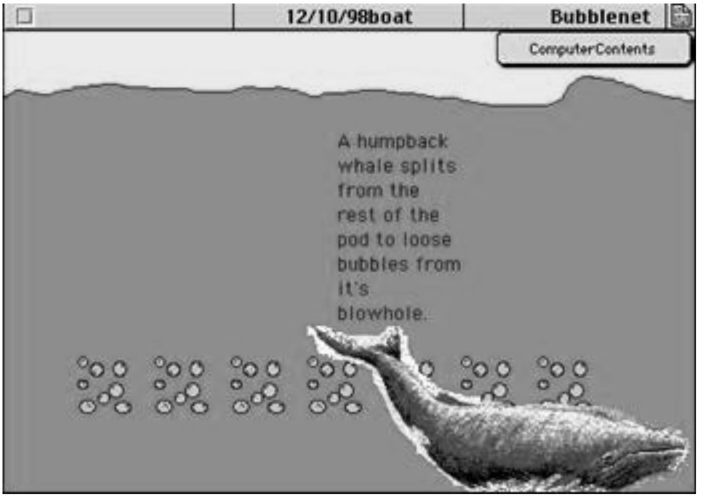
The classroom for focus and comparison students featured eight computers distributed within clusters of desks throughout the room; two more computers were located on the sides of the room, not designated for any particular workstation but for general use. All computers were Macintosh with Internet access and assigned hard disk space for students to save their design work in team folders on a daily basis. A big-screen television monitor, a whiteboard, and a rug area were located at the front of the classroom. Colorful bulletin boards displayed a mural of ocean animals and fish along the length of the far wall. Each team was assigned a computer with surrounding desks as their workstation.

CURRICULUM ACTIVITIES

The project started for both the focus and comparison class with an inquiry component in which students posed individual questions of interest within a curricular topic. The topic for the project reported here was marine biology. Some student-generated questions included, "How do tide pools work?" "How do whales in pods cooperate?" and "Why do fish swim in schools?" Students were also introduced to the software design environment, Logo Microworlds, in three sessions in which they learned the interface for using text and graphics to create a food web presentation. Students then conducted information research to answer to their questions via online and print resources and outside experts, and they programmed simulations that displayed what they learned about their questions. Teams worked together to create software that incorporated each member's simulation.

Figure 1, for example, is a screen capture from the first phase of Daniel's simulation. The animation demonstrates how pods of humpback whales use bubble nets to trap krill on the surface of the water. In addition to Daniel's simulation, the final product from his team also contained simulations by each of his team members addressing how male seahorses give birth, how scuba equipment works, and what kinds of submersible watercraft marine researchers use. Tying these distinct simulations together were shared pages like a title screen, the table of contents linking to each simulation, and a credits page thanking the teacher and researchers for their help.

Figure 1. Screen Capture from Student-Created Whale Simulation



The process described above did not take place in a strictly linear sequence. The iterative cycle of question posing, planning, research, design, programming, and continued research and revision is one of the hallmarks of design learning (Marshall, 2000; Perkins, 1986). The teacher was thus responsible for helping students cycle through these activities in productive ways—scaffolding student inquiry and organizing instruction about marine biology. She was engaged in modeling inquiry and assisted students with information searches, developing and revising inquiry questions, and evaluating their simulations to determine if inquiry questions had been addressed. Science content was almost exclusively the teacher's domain. She conducted many whole-class sessions with students, introducing and discussing particular aspects of marine biology such as habitats, scientific exploration of ocean environments, different life forms, and food webs. In terms of programming instruction, the teacher partnered with the first author to provide a basic overview of Logo programming skills and principles on the first two days of the project. She also provided some programming and design help as teams worked independently after the overview, but students largely provided this assistance to one another on a basic level (this will be discussed further in the Results section). Researchers and highly skilled student programmers, some eventually surpassing the researchers' knowledge, were also available to deal with complicated programming problems that the majority of students could not fix.

DATA COLLECTION AND ANALYSIS

We used several qualitative and quantitative methods to (a) document classroom activities and team interactions and (b) interview students about their project experiences. In the following sections, we describe those procedures and instruments that pertain to the analyses in this article.

Classroom and team observations

Two video cameras with remote wireless microphones were used to collect the data for the investigation of collaboration patterns. Two teams were videotaped and recorded each day for all 10 weeks as they collaborated at their workstations, one with each camera and microphone. The camera captured all activity at a given team's workstation: all programming and other work on the computer, drawing or reading research material at the adjacent desk space, and other work. In addition, we kept daily field notes documenting classroom activities and discussions with students.

Our main focus for this article was the everyday team interactions during the crucial "middle" phase of the marine biology design project, weeks 3–6. During this middle phase, all students were supposed to have completed their initial inquiry research on their questions, although some additional research was necessary later in the process for some designers, and most teams had finished their shared screens (table of contents, title screen, and so on). Students were then supposed to begin work designing and programming their individual simulations that would address their inquiry questions. The combination of independent and collaborative work that occurred during this time, with all students ostensibly having a high degree of ownership over their own simulation ideas yet fourth-graders needing help with manifesting their design screens, made these weeks particularly fruitful for this analysis.

We used a combination of qualitative methods to create a descriptive framework for the collaborative patterns that emerged. Erickson's (1992) method for microanalysis of video was used to create video annotations and a comprehensive list of the kinds of fourth/fifth-grade collaborations that we saw. We were interested, however, in not only documenting various kinds of peer-to-peer helping but also tracing trajectories of interaction and the flow of collaboration. After the list was created, we drew on grounded theory (Strauss & Corbin, 1998) and hermeneutic phenomenology (for a review, see Laverty, 2003) to develop what ultimately emerged as a descriptive flowchart of the progression of helping practices in collaborative episodes. The hermeneutic methodology is meant to facilitate an understanding and interpretation of our video data by creating a conversation between the collaborative patterns contained in the footage—the helping practices that are revealed in individual episodes and within and across groups—and our own researcher perspectives that are situated in traditions of sociocultural, constructivist, and constructionist perspectives on educational technology and classroom practices. Thus, although the results of our video analysis are highly grounded in the data, as is consistent with grounded theory, our interpretation and organization of those results are necessarily colored by the theory and practice that inform our work. Because the framework that arose from this process is a result rather than a coding scheme or rubric, it will be described in the Results section.

Interviews

At the end of the project, debriefing interviews were conducted with all students. Students were asked the following three questions that gave them opportunities to reflect on their own situation and that of students in the other grade level: (1) Can you think of any differences between fourth-graders and fifth-graders in terms of how they worked on the simulation design project? What are they? (2) What does it mean to be a fourth-grader working on this simulation design project? (3) What does it mean to be a fifth-grader working on this simulation design project? Focus fifth-graders were distinct in that when answering the second question, they could 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.

One might wonder why these three questions were designed in such a seemingly vague manner. In this analysis, rather than prompting students to talk about specific issues, we 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 fourth-graders and fifth-graders 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 (1996) emphasizes the importance of attempting to "locate learning throughout the relations of persons in activity in the world" (p. 27). It is this directive that influenced the choice here to ask students to reflect not on 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.

All interviews were conducted by the authors or a graduate student who had been present in the classroom weekly throughout the project; thus, students spoke candidly to interviewers with whom they were already acquainted and who were also participant-observers in the design classroom. The interviews were videotaped, transcribed, and analyzed using interpretive methods to create an emergent coding scheme reflective of the variety and complexity of student responses. This scheme was then used to code the entire corpus of interviews, and counts were made of students' breadth of understanding in their discussion of various aspects of the project experience by two independent coders. The inter-rater reliability for these codes was 90%; divergent codings were discussed after reliability to arrive at one coding. These counts were then used in an analysis of variance (ANOVA) to determine statistically significant differences among students at various levels of experience with learning-through-design and programming.

RESULTS

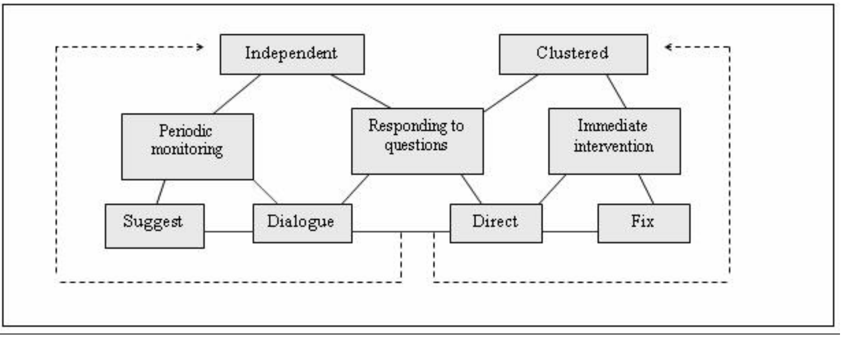
FRAMEWORK: PATTERNS OF STUDENT COLLABORATION

In creating a framework of interaction patterns for the focus class, a dichotomy of team organization was revealed. In both classrooms, team interactions seemed to be structured in one of two broad ways: clustered work or independent work. Clustered work describes a pattern wherein all or the majority of team members hover around the workstation computer and contribute physically or verbally to screen creation. In independent work, students in a given team simultaneously perform different activities in parallel: programming, researching, working on plans and calendars, and drawing screen ideas. Independent team members are within earshot of one another, however, and are often at the same workstation while doing these different tasks, so communication and collaboration among members still occur. Some teams worked primarily in one of the two patterns, but even among those mainly clustered or independent teams, there was some variability. Mainly independent or clustered teams could also temporarily work together in the opposite pattern, as will be demonstrated in the data episodes that we present, but teams usually went back to their default collaborative pattern afterward.

The next step in analyzing interaction patterns after establishing general group organization was to determine what fifth-graders were doing to help fourth-graders learn to negotiate the terrain of beginning their own simulations. At this point in the project, students divided their work time such that multiple students in a given team had the opportunity to work in Microworlds during a single class period. Consequently, in each team session on video, there were sufficient opportunities to examine extended episodes of fourth-graders working in Microworlds. Because we were specifically interested in fourth/fifth-grader interaction patterns that would help newcomers learn about software design, this particular analysis was limited solely to video footage involving fourth-graders making their simulations.

During the process of moving from a list of interaction patterns to a descriptive framework, what emerged was not a list of discrete categories but rather interrelated patterns of fluid fourth/fifth-grader exchanges. For both clustered and independent teams, fifth-graders responded in multiple ways to fourth-graders' work. These patterns are represented by a flow chart showing the multiple forms of collaboration seen in the data (see Figure 2). The first level describes the typical team configuration as described earlier: clustered or independent. The second level of organization in the chart describes how fourth/fifth-grader interaction is initiated. We identified three main ways that a socializing or instructional interaction began: periodic monitoring, responding to questions, and immediate intervention. The third level describes specific strategies for providing particular kinds of help. In a given conversation, many fourth/fifth-grader collaborations contained several of these third-level strategies.

Figure 2. Emergent Framework of Helping Patterns Within Team Configurations



ILLSUTRATIVE EPISODES

To demonstrate how the framework helps illuminate and describe the interactions that we saw, three extended episodes are presented, one for each of the initiating patterns. Within these episodes, we capture fluidity of discourse and activity, temporary restructuring as teams move back and forth among multiple levels of the framework, and fundamental differences between focus and comparison classroom collaborations. We also discuss affordances for learning and socialization of the various patterns and helping approaches.

Episode 1: Independent, periodic monitoring

The first episode is an example of a group that typically engaged in independent work, with fifth-graders often displaying the periodic monitoring pattern. It comes from the same team as the whale screen capture shown earlier. This is a team from the focus classroom, in which fifth-graders had more extensive experiences with Logo programming and the learning-through-design approach. In this episode, fifth-grader Daniel points out for fourth-grader Sarah the difference in Logo Microworlds between programming objects using their command windows (where only short command strings can be entered) and programming using the procedures page (where the designer can write longer procedures and link them together to control multiple objects at once). Procedures page programming represents a more sophisticated level of skill than embedded object programming, and it is representative of the kind of higher level knowledge about programming demonstrated by many fifth-graders in the focus class.

At the beginning of this episode, Sarah is sitting alone at the computer at her team's workstation. She is working on her screen about submarine exploration, while Daniel talks at an adjacent table with members of another team about an upcoming field trip to the aquarium. The other two members of Daniel and Sarah's team are in the rug area of the classroom having a discussion with the teacher about Internet searching. Daniel leaves his conversation and walks behind Sarah to observe what she is doing on the computer, just as Sarah opens up an object command window and begins to type a procedure to animate the submarine she drew earlier. The following discussion ensues:

01	Daniel	What are you doing?
02	Sarah	I want this [points to the submarine] to float down to the bottom, like this. [drags the submarine down with the mouse] Then the *shark* will come along!
03	Daniel	Why are you typing it in the window?
04	Sarah	Ummmmm. . . . What?
05	Daniel	It's easier if you use the procedures page.
06	Sarah	[looks at Daniel quizzically, says nothing]

07	Daniel	That way you can make it a bigger procedure for the shark too.
08	Sarah	Oh. So I can do it all at once? [long pause] Well. . . where do I type it then?
09	Daniel	Click here [pointing on the screen to the icon for procedures], and write it there. Use a "wait," and then write what you want for the shark after.
10	Sarah	Okay. [clicks on procedures] Where should I write it?
11	Daniel	Well you can, I mean, anywhere, really. But let's put it on the bottom, because it's new.
12	Sarah	Okay. [voice-over as she is typing] "Toooo shaaaark. . . "

The discussion begins with Daniel initiating a *dialogue*, questioning Sarah about what she is doing (turn 01) and her programming strategy of using object windows (turn 03). Sarah describes her idea of having two moving objects on the screen and tells Daniel how she wants the animation to look (turn 02). Daniel then *suggests* a fundamental change in Sarah's programming approach (turns 05–07): the more sophisticated strategy of linking multiple commands together using the procedures page. Sarah apparently finds this new approach compelling, but she is unsure how to do it and asks for more information (turn 08). At this point, the interaction shifts from being a dialogue about possible strategies and becomes a pattern wherein Daniel is *responding* directly to Sarah's questions and telling her how to proceed. He *directs* her actions by telling her where to click and to write "wait" in between her commands (turn 09). Sarah wants to know where on the page she should write her procedures (turn 10), and Daniel *directs* her to write them on the bottom of the screen (turn 11). Sarah then begins typing a procedure to animate her shark (turn 12) and Daniel watches. Sarah does not have any other questions immediately, so Daniel goes back to talking with team 6.

There are several important features of this episode to point out, which will become particularly relevant later in comparison with subsequent episodes. First, Daniel walks away from his conversation with team 6 to check up on Sarah, not in response to a request from her but on his own. This is the hallmark of the periodic monitoring strategy: Fifth-graders check on fourth-graders' progress by temporarily pausing their own activity and visiting the computer where fourth-graders work. Second, upon seeing that Sarah is using a less effective programming strategy, Daniel initiates a dialogue with her about her approach rather than telling her that she is wrong and should change. At no time does Daniel tell Sarah what to do in an unsolicited manner. His introduction of the idea of the procedures page is a suggestion, beginning with the phrase, "it's easier" and using statements of potential, like "you can," rather than telling her explicitly to alter her strategy. When he eventually directs her, it is entirely in response to her questions. Finally, the episode begins and ends with Sarah working alone and Daniel doing something else away from the immediate vicinity of the computer. Daniel does not hover over Sarah as she writes her commands to make sure she is doing it correctly. He helps her through the transition from object window to procedures page and then leaves her to work on her own.

Episode 2: Clustered, immediate intervention

The second episode is from a team that almost always worked in a clustered format. The boys on focus team 7 liked to sit all together, chairs in a tight row in front of their group computer, when it was fourth-grader Ethan's turn to work on his simulation. Ethan typically sat in the middle to control the keyboard and mouse, with fifth-graders Michael and Leo on either side. In this particular episode, the boys are working on the procedures page. Ethan wants to write a procedure to make a manta ray swim across the screen and then hide behind a rock, and Michael and Leo tell him how to do it. For readers to see how the program code evolves as a result of their conversation, we have included the command lines in square brackets following conversational turns in the transcript.

01	Ethan	Okay. [speaking as he types] Glide two hundred and one.	[*glide 201*]
02	Michael	No, 20 <u>space</u> one. The one is the speed.	
03	Ethan	Oh, okay. [types a space in his command line] Okay.	[*glide 20 1*]
04	Leo	Right.	
05	Ethan	Now, I want it to go fast, like SPPEEWWW! [loudly, moves his hand across the space in front of him very quickly]	
06	Michael	Hahahahha!	
07	Ethan	So, I'll put speed 2. [types]	[*glide 20 2*]
08	Leo	That's not going to be much faster than 1.	
09	Michael	Yeah, make it more. How about 5?	
10	Ethan	Yeah, 5. [types]	[*glide 20 5*]

11	Leo	Okay, now wait.	
12	Ethan	Yeah, wait 3, then . . . hide turtle. [types]	[*wait 3, ht*]
13	Michael	Why did you put 3?	
14	Ethan	It doesn't matter, it's just how long the wait is.	
15	Leo	Yes it does.	
16	Michael	Well, do you want it to just, like, <u>disappear</u> after? [moving his arm with the same motion Ethan did earlier, but without nearly as much enthusiasm] Like, "spew" and then it's gone?	
17	Ethan	Well. . .	
18	Michael	Or do you want it to <u>stay</u> over here [pointing to the far left of the screen] and then go?	
19	Leo	Yeah, 'cause 3 is not a very long wait.	
20	Ethan	Okay, how about wait 8? [types]	[*wait 8, ht*]
21	Michael	Good	
22	Ethan	[clicking over to screen view] Okay, okay. Let's see how it looks!	

In this episode, the *intervention* begins as soon as Ethan types a single line on the page. He forgets the space between his two command inputs, distance and speed (turn 01), and Michael corrects him right away (turn 02). In his turn, Michael uses the *fix* strategy in that he identifies something Ethan has done incorrectly, and he takes immediate action to correct it. In some cases, fifth-graders would actually take control of the mouse and/or keyboard and physically fix whatever they perceived to be wrong, but here Michael only uses words to repair Ethan's buggy code. Ethan changes the code to remove his error (turn 03), and Leo tells him that he is "right" (turn 04). Ethan then describes how he wants to change the code again to align with his idea for the screen, so that the manta ray will move faster (turns 05–07). Leo and Michael both assert that Ethan's new input for speed will not give him the fast movement he wants (turns 08–09), but Michael also *fixes* Ethan's code and says explicitly that he needs to "make it more." Michael then *suggests* a higher value of 5, which Ethan agrees with and complies (turns 09–10). The rest of the episode, in which the boys discuss the part of the procedure that will make the manta ray disappear, also focuses on the question of appropriate input values, but the collaborative pattern looks subtly different. After Ethan writes his code, Leo and Michael engage him in a *dialogue* about why he chose a value of three for his "wait" command (turn 13) and how that value may or may not correspond to the way Ethan wants the animation to look (turns 15–19). Ethan comes up with his own higher value of 8, which Michael confirms is "good" (turns 20–21). The boys then go to the animation screen to see the results of Ethan's written code.

As an exemplar of the immediate intervention pattern, there are several key features of this episode that stand out. First, Michael jumps in to fix Ethan's initial mistake before Ethan can even hit the return key. During the first half of the episode, Ethan is being told explicitly what to do by Michael in particular, and each of his code changes are evaluated as to their correctness by both fifth-graders. Ethan has no opportunity to recognize his own mistakes or realize for himself that he tends to overestimate the intervals between input integers. Further, Ethan actually asks only once for Michael's or Leo's opinions or directions to create the best procedure, and that occasion is only to request confirmation of his own suggestion for a wait value. Ethan does not seem upset by the fifth-graders' otherwise spontaneous input, but nor is it explicitly requested. Given the relative lack of ownership that Ethan seems to have over his own coding process, it would be easy to cast this episode in an entirely negative light from the perspective of collaborative helping. However, we must also consider the task at hand and the relative sophistication of what the boys are doing.

During the entire conversation, all three boys are looking only at a screen full of command code and not at the graphic animation page. To view the resultant animation, they have to go to the animation page and click on a button or object to activate the procedure. Because of this aspect of the Microworlds interface design, a typical novice programmer strategy is a process of trial and error, wherein the student constantly clicks back and forth between animation page and procedures page: writing code, launching the animation, adjusting the minutiae of values and codes, viewing the animation again, and so on ad infinitum. In this episode, however, Michael and Leo model for Ethan how they can envision the animation just by looking at the commands and inputs. They do not need to view the animation to know that the manta ray will be too slow and that it will disappear too soon, because they can see through the code to its result. Similar to the previous episode with David and Sarah, the fifth-graders on this team thus help the fourth-grader engage in a much more sophisticated programming practice than he would be able to execute on his own. Although Ethan lacks critical opportunities to find and rectify his own mistakes, he also gains access to a type of cognitive apprenticeship through being able to talk through his code with Leo and Michael in the clustered format.

Episode 3: Independent, responding to questions

The third and final episode comes from the comparison classroom, in which fifth graders only had a very basic exposure to programming the previous year and no experience in the learning-through-design format. It is an example of the *responding to questions* pattern in the independent team format, and it also demonstrates the lower level of engagement with programming and helping attitude characteristic of the comparison class. Within this longer episode, however, we also see a brief pattern of immediate intervention; the fifth-grader remains with the team temporarily after the initial question has been answered.

Fourth-graders Frankie and Jason are sitting together at the computer (although it is Frankie who is working on his idea), and fifth-grader Charlotte is reading a book about dolphins at the table adjacent to her team's computer. Frankie is working on a simulation about tide pools, and he has completely filled the screen with life forms of various sorts: starfish, anemones, sea cucumbers, and crabs. To make each life form and animate it, Frankie creates a programmable object (called turtles in the Logo environment) and then must paste a picture (called a costume) of a marine life form on top of the object. As the episode begins, Frankie is trying to paste a picture of another starfish into the already crowded scene.

01	Frankie	[silently tries to paste, but the starfish does not appear] Man!
02	Jason	What happened?
03	Frankie	It didn't go. [tries again] Man! Still! This won't paste.
04	Jason	You can just press Command-C. [reaching for keyboard]
05	Frankie	[pushing Jason's hand away] I know! That's not why.
06	Frankie	[leaning around the computer and waving his arm in front of Charlotte] Hey, how do you paste?
07	Charlotte	What? <u>You know</u> how to paste.
08	Frankie	Yeah, but it won't go.
09	Charlotte	[sighs and gets up to look at the screen, leaning over next to Frankie] Where do you want to put it?
10	Frankie	[pointing with his finger on the screen] Here.
11	Charlotte	Where's your turtle?
12		[long pause, everyone looks at the screen]
14	Jason	You don't have a turtle.

15	Frankie	[laughs, hits himself in the head] Stupid! I forgot the turtle!
16		[everyone watches Frankie make the turtle and paste]
17	Jason	[looks at Charlotte] That's cool, huh?
18	Charlotte	Yeah, but we're gonna have, like, no room, I hope you guys know. You're gonna have to move some of this stuff.
19	Frankie	Why?
20	Charlotte	Cause nothing can go forward! It's too crowded.
21	Frankie	Oh. Okay.
22	Jason	We'll delete some stuff.
23	Frankie	[selects the eraser tool and begins to move it toward the scene]
24	Charlotte	Ahhh! What are you doing? You're gonna mess it up!
25	Frankie	You said to delete some.
26	Charlotte	No, no, you can't erase turtles. You have to cut turtles.
27	Frankie	Oh, whoops. [selects the scissors tool instead]
28	Charlotte	Whatever. [goes back to her book]

This episode illustrates a different kind of *responding to questions* than in the previous two. In the other illustrative episodes, when fourth-graders ask a question about how to do something, it is prefatory to their actually performing the act in question; that is, they ask before they try it themselves. Here, however, Frankie tries to paste his starfish several times without success (turns 01–03), identifies that there is a problem that neither he nor Jason can solve on his own (turns 03–05), and appeals to Charlotte for help (turn 06). This sort of situation was most common in the independent team configuration: When independently working fifth-graders were retrieved with a question by fourth-graders, it was generally because there was some kind of buggy code or other mistake that required help. Interestingly, however, in this episode, Frankie does not initially say there is a problem; instead he asks for information (turn 06). Charlotte is annoyed by such a low-level question about pasting, and she derisively implies that Frankie should not really need her help (turn 07). Then Frankie repairs his meaning and indicates that there is actually a problem that has already happened, whereupon Charlotte decides to help and initiates a *dialogue* about the location for pasting (turns 08–09). In the next brief segment, it becomes apparent that Frankie has made the somewhat humorous mistake of attempting to paste a costume into a blank space rather than on a turtle object (turns 10–16). Jason and Frankie have some agency in how this mistake is caught, in that they realize the error in response to Charlotte's question (turn 11) rather than being told explicitly what is wrong. It is impossible to discern for certain from this episode the intent behind Charlotte's question. She could be being sarcastic, which would be consistent with her earlier stance toward Frankie's need for help (turn 07), although her tone in this turn is much more straightforward than before. She could be genuinely confused as to the location of the destination object, which would also be reasonable given the crowded and chaotic screen. Or she could be asking out of a desire to give Frankie a chance to correct his own mistake, a helping technique that was often modeled by researchers and the teacher. In any case, Charlotte's question, however it is intended, affords both Frankie and Jason the ability to recognize and laugh at the error rather than continue to be frustrated by it.

In the second half of the episode, Charlotte's stance toward the fourth graders changes when she *responds* to another question, after Jason asks for her opinion on the look of the tide pool screen (turn 17). This part of the interaction looks more like a clustered pattern. Charlotte asserts that there is a much bigger mistake that the boys do not yet realize, which is that they have made the screen so crowded with objects that no animation can take place (turns 18–20). Her recommendation, that they will have to move some objects, is not phrased as suggestion but rather as a *fix*: Something is wrong, and she tells them explicitly how they should repair it. Frankie and Jason comply with her assertion (turns 21–22), but as Frankie selects the eraser tool, Charlotte uses a dramatic *immediate intervention* to stop him in the act (turn 24). He is about to make yet another mistake, in that his use of the eraser will not eliminate any of the turtle objects, but it will erase parts of the painstakingly drawn graphic background of water and rocks. Charlotte again *fixes* the error and tells Frankie that turtle objects have to be deleted using the "cut" function, not the eraser tool, which is for graphics (turn 26). Although clearly diminishing Frankie's agency, this exchange demonstrates a pragmatic, if not necessarily pedagogical, advantage of the clustered intervention pattern: Avoiding a big mistake such as the one that Frankie nearly makes saves time and effort on everyone's part. But at this point, Charlotte has had enough. Clearly frustrated with the boys and their lack of understanding, she then declares, "whatever," and leaves (turn 28), returning the team to an independent configuration.

Similar to the previous two examples from the focus class, in this comparison class episode, the fifth-grader also helps fourth graders on her team engage at a higher level with Microworlds than they can on their own. As the discussion unfolds, it becomes clear that Frankie and Jason are preoccupied with creating a static representation of a tide pool on the screen, but they have not considered actually animating the scene at all, nor are they differentiating between background drawings and turtle objects. Charlotte's various comments aimed at *fixing* Frankie's screen illustrate her understanding that programmers need to think about animations not as static representations but as unfolding over time as objects move and interact with one another, and that Frankie should be creating the initial state of his animation with the end state also in mind. This is a big conceptual leap for the fourth-graders to make, but compared with the other two episodes from the focus class, it is a fairly basic one and demonstrates the overall lower level of comparison class activity. Whereas at this midpoint in the project, most focus teams were dealing with moving fourth-graders toward more sophisticated programming strategies, many comparison fourth-graders had not even engaged with writing very limited code. In this example, Frankie has trouble even thinking about movement at all, let alone how to make it happen by using commands and procedures.

Cross-episode findings and comparisons

From a socialization perspective, the various helping strategies employed by the fifth-graders in all these examples clearly lighten the pedagogical load for the teacher in terms of programming. Having worked in classrooms for previous research in which the introduction of Microworlds is completely novel, and thus all students are novice programmers, we can assert that many of the issues seamlessly addressed by experienced fifth-graders in these examples would have resulted in raised hands and long delays in a more homogenous classroom. Countless times we have seen many students wait to have their questions answered by the limited-resource expertise of teachers or researchers. Further, in situations in which novice programmers do not realize that they are making mistakes or working at a low level of engagement, their activity often goes unaddressed entirely in a homogeneous situation because the teacher is typically completely occupied with raised hands and lacks time to do any *monitoring* of his or her own. In this project, however, the teacher's time was freed up considerably by the distributed nature of programming expertise across student teams, and she was able to focus much more on the scientific inquiry portion of the curriculum.

Further, in all the episodes presented, the fifth-graders' help clearly serves to not only correct mistakes or answer basic questions but also to raise the entire level of programming activity for their fourth-grade teammates. We identified multiple layered and interrelated patterns of help-giving that fifth-graders appeared to use in purposeful ways. We thus propose the term *peer pedagogy* to describe these complex interactions. In contrast to existing research on collaborative learning that emphasizes isolated instances of "help," the results from this analysis suggest that experienced learning-through-design students engaged in a much more intentional process that was explicitly focused on learner improvement. This is not to say that all fourth/fifth-grader collaborations were ideal and always geared toward positive learning outcomes. Charlotte's exasperated "whatever" and subsequent leaving at the end of the third episode is also typical of the occasional fifth-grader frustration in both classrooms. Our results and the episodes that we have presented, however, demonstrate that students can collaborate with one another in a highly pedagogical manner far beyond the lesser degree of awareness and intention typically described in existing literature.

In terms of focus-comparison differences and the relative effectiveness of various peer-to-peer helping strategies, our results demonstrate that the presence of experienced students who are not just trained in rudimentary basics (like comparison fifth-graders) but have a considerable degree of experience and expertise results in higher levels of engagement and understanding for all students. Our results also show that it is perhaps overly simplistic to make sweeping judgments about the value of one strategy over another. Clustered patterns with immediate intervention seem to take away agency and decision-making from fourth-graders, but they also make visible how more experienced students think through the programming process and can help to avoid catastrophic mistakes. Independent patterns and strategy dialogues seem more equitable and allow fourth-graders opportunities to both make and rectify their own errors, but there is always the risk that significant problems will occur in the absence of experienced students, or that good advice given in a less emphatic format will not be taken up. The variety of patterns we observed, however, is a testament to the complexity of peer pedagogy in this context and illustrates that fifth-graders approached helping fourth graders learn in many different ways.

STUDENT VOICES ON COLLABORATION

The wide variety of helping patterns described in the previous section lead one to wonder about how students perceived their actions and the actions of others. How aware were students of their differences, not only in terms of interaction patterns but also in general? Certainly in order to claim that fifth-graders are being explicitly pedagogical in their interactions, we should be able to demonstrate that students are aware of their helping roles and activity goals. Below are two segments of interview transcripts, provided to give the reader examples of the way that students talked about their roles. The first segment is from an interview with Brian, a fifth-grader in the focus class, and the second is from an interview with Ivan, a fourth-grader in the focus class. The interviewer in each case, the first author, is indicated by INT.

> INT: What does it mean to be a fifth-grader working on this project?
> Brian: Well, we have experience, so sometimes we help them with the simulations.
> INT: How do you mean?
> Brian: Well, programming [pause]. But it's not just programming, 'cause Melody [a fourth-grader on Brian's team] is pretty good at that. But, like, if I see something that's not planned well, or maybe overscheduling, then I'll say something about that.

> INT: What does it mean to be a fourth grader working on this project?
> Ivan: Well, um, it's [pause] . . . to know that there's people older than you, who know more and are more experienced at it.
> INT: Mmm. What else?
> Ivan: Well, you know that you can always get help from them, because of what they've done before on it.

In each case, both Brian and Ivan discuss their respective roles as fifth-grader and fourth-grader in social terms; the experience of each is inherently defined by collaborating with the other. Further, the relationship between fifth-graders and fourth-graders in both responses is configured as that of not just collaborating but also specifically giving or receiving help. Additionally, Brian first describes a general type of help and then expands his response to include the more specific skills of programming, planning, and scheduling. Ivan's description, on the other hand, also focuses on the difference in previous experience, but when prompted to elaborate, he describes helping but doesn't specify help with what. These characteristics of the student interviews—an emphasis on help and a more fine-grained articulation by focus fifth-graders—are reflective of just some of the compelling overall patterns we found in our analysis. In reporting results from the interview analyses, we first describe the coding scheme that emerged from student interview transcripts and then move to our analysis of students' awareness of role differences by class and grade level.

A decision was made to treat all three questions about fourth/fifth-grade differences and identity issues as one unit of analysis because of the nature of student responses. Rather than limiting their talk to only fourth-graders or only fifth-graders in response to the corresponding questions, student answers to any, and sometimes all, questions contained information relevant to differences (question 1) and the meanings of their own and others' roles (questions 2–3). Consequently, it made sense to code the entire conversation as one unit. The main categories that emerged from student responses were knowledge differences, affective differences, and social role differences. There was also a fourth code for "no difference." The descriptions that students gave of knowledge differences were more multifaceted than could be captured by a single code, however. Students cited several different types of knowledge differences: (1) general or unspecified knowledge (e.g., "fifth-graders seemed to know more"), (2) knowledge about programming specifically (e.g., "they were newer to Microworlds than us"), and (3) knowledge about specific aspects of design other than programming (e.g., "fourth-graders didn't know how to spread out the work"). Students also mentioned affective difference (e.g., "you feel kind of dumb at first"); this was a single code and not broken down further.

The social roles code refers to differences that 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 Brian's and Ivan's responses at the beginning of this section. Like knowledge differences, the picture painted by students was more complex than the initial category. They cited the following types of social roles: (1) general or unspecified giving and receiving help (e.g., "we had to help the fourth-graders to know what to do"), (2) giving or receiving help with programming (e.g., "you could always ask a fifth-grader if your animation wouldn't work"), and (3) giving or receiving help with other specific aspects of design (e.g., "we always helped, 'cause fourth-graders couldn't make the schedule by themselves"). Although some students also mentioned "no difference," these were typically comparison class students. A few focus students who claimed that there were no differences in response to the first question later contradicted themselves by talking about differences in response to the "what does it mean?" questions. These subcodes for knowledge (3), affective (1), and social role (3) differences make up seven types of observations that 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 they were highly aware of their collaborations with one another and the role of previous experience in affecting their interactions.

To assess the breadth of characteristic differences students cited among all groups of designers—fourth- and fifth-graders in the focus and comparison classes—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 that students mentioned. For example, a student 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. Focus fifth-graders spontaneously generated more types of difference ($M = 4.893$, $SD = 1.368$) than focus fourth-graders ($M = 2.800$, $SD = 1.082$), comparison fifth-graders ($M = 2.933$, $SD = 1.387$), or comparison fourth-graders ($M = 3.200$, $SD = 1.265$). ANOVA and a Tukey post hoc revealed that focus fifth-graders' breadth of awareness was significantly greater than that of any other group ($MS = 4.713$, $F = 2.855$, $p < .05$). None of the other groups was significantly different from one another.

These results demonstrate several things. First, there clearly existed a dynamic in both classrooms wherein students perceived differences between fourth-graders and fifth-graders despite comparison fifth-graders' limited previous experience with Microworlds. Even though comparison fifth-graders had only 3 weeks of programming in mathematics during the previous year, which was not at all comparable with the long-term design experience of focus fifth-graders, this difference was noticed and became highly salient in comparison students' reflections. Additionally, the existing age dynamic in both classes may have also affected students' perceptions of general knowledge differences. Focus fifth-graders, however, were able to talk about differences between those with experience and those without in a much more sophisticated way, and their breadth of awareness and articulation significantly surpassed that of the other groups.

DISCUSSION

Our goal was to describe and understand the nature of everyday collaborations between experienced and inexperienced students in a project-based environment in order to illustrate how students can learn and perform among themselves some of the socializing and pedagogical functions typically assumed by the teacher. We proposed the term *peer* *pedagogy* to describe the strategic, reflective, and effective nature of peer helping observed in team interactions with experienced members. The focus of our discussion is to address possible motivations and structural features that facilitate these types of peer interactions. The results of our analysis have implications for understanding the nature of collaboration, both in classroom communities and apprenticeship contexts at large.

One contribution of these findings deals with the wide variety of collaborative helping interactions that we observed. Students in both classes displayed many different ways of helping and working with one another—a much richer variety of interactions than that documented by traditional collaborative learning research (see Webb, 1989). The motivations behind these actions, however, are not fully discernable from the behavioral data. Questions arise regarding how experienced students think about their interactions with beginners, and the choices that experienced students make regarding how they help beginners and engage them in design. Why did some fifth-graders in clustered teams choose to hover over fourth-graders' shoulders, whereas experienced students in independent teams retreated to a greater distance away? Certainly these interactions were likely co-constructed, but we did not observe beginners in clustered teams needing more guidance or asking many more questions than their independent counterparts. On another level of detail, why did some experienced students direct beginners in fixing their own mistakes, whereas other experienced students jumped in and did all the fixing themselves? Why, for that matter, did some experienced students give unsolicited help or fixes to beginners whereas others engaged in design dialogues? It could be that all fifth-graders acted in ways that they genuinely believed to be most helpful. Equally likely, however, is that experienced students' interactions with fourth-graders were more a function of their own preferences and existing pedagogical models that they had experienced. An interview-based examination of how students viewed their roles as fourth- and fifth-graders, or as inexperienced and experienced students, provided some insight into these questions; however, more research is needed on children's explicit motivations and reasoning about peer pedagogy.

In the interview results, fifth-graders' greater breadth of understanding shows that fifth-graders continue to develop knowledge, insight, and a more reflective perspective on the design project and its apprenticeship interactions through their experience during their fifth-grade year. Recall that the interviews took place after project completion; thus, the insights shown by fourth-graders in the postinterviews potentially represent the level of design knowledge and understanding with which fifth-graders enter their second year in the project. Yet by the end of that second experience, fifth-graders have developed reflections on the project that far surpass their fourth-grade classmates and their same-age comparison cohort. Thus, learning in the classroom design community does not end with a fourth-grader's attainment of skills sufficient to participate fully. Rather, fifth-graders continue to not only increase their programming skill but also learn about the nature of practice by observing, working with, and helping fourth-graders. Thus, the old adage that one never really learns something as fully as when one has to teach it holds true yet again. Existing studies of collaboration and communities of practice, however, have not examined this aspect of learning; much potential for future research resides here.

With its long-term and process-based features, the learning-through-design project has arguably more in common with apprenticeship learning than with traditional collaboration approaches. Existing literature provides a variety of perspectives on apprenticeship: how experienced participants structure beginners' use of particular artifacts (Rogoff, 1993), how participants negotiate and co-construct shifts in different phases of activity (Wenger, 1998), detailed descriptions of particular apprenticeship interactions at isolated moments in time (Hutchins, 1996; Schön, 1986), and even instances of failed apprenticeships and their shortfalls (Hodges, 1998; Lave & Wenger, 1991). Although authors such as Lave and Wenger and others have argued that apprenticeship cannot take place in formal education because the process of identification and the structure of discourse are problematic (Linehan & McCarthy, 2001), we found that the reproductive features and the patterns of collaboration observed in the learning-through-design project carry many of the same characteristics found in sociocultural studies of apprenticeship learning. We argue that our findings about the nature of student collaboration in this project—in which the coparticipation of fifth-graders raises the level of fourth-grader activity to more advanced programming or design concepts—also contribute to a general understanding of the character of old-timer–newcomer discourse and interactions.

A structural feature of the learning-through-design project and the school where we conducted research is critical: the composition of mixed-grade classrooms and mixed-grade teams. This feature guarantees that there are always students who come with previous project experience. More important, inexperienced students know that the following year it will be their turn to assume the roles held previously by their fifth-grade team members and to apprentice the new generation of fourth-graders into project practices. Such a mechanism ensures that collaborative learning has a history and future, and it also allows for change as new students enter and leave the classroom community. In analyses of other learning-through-design projects, we found evidence in teams' planning meetings that experienced fifth-graders explicitly reference their prior experience when helping other team members in their software design decisions (Marshall, 2000). We realize that the structure of most school organizations is not set up to support such long-term curricular implementations. But the difficulty alone should not be reason for exclusion; rather it should invite educational theorists and practitioners alike to rethink how we can organize collaborative learning environments with such reproductive features (Barab & Duffy, 2000).

CONCLUSIONS

Questions about the patterns of collaborative interactions in project-based learning were the driving force behind this study. On a basic level, this work contributes to the growing body of research on project-based learning and the larger research literature on collaboration by providing a detailed account of how collaboration between students can be configured to create classroom communities of learners. On a theoretical level, the patterns of collaborative interactions observed in learning through design provided evidence for the possibility of locating apprenticeship learning in classroom communities. Additionally, the results from this study offer an opportunity to rethink approaches to curricular reform efforts that so far looked only at institutions and teachers, rather than at students, as carriers of change. Finally, our discussion of the collaborative patterns that we saw, and students' awareness thereof, as not just moment-to-moment assistance but rather as strategic and thoughtful peer pedagogy, elevates the study of student collaboration to new levels and forces us to consider and respect the complexity of children's activity as they shoulder the responsibility of helping one another learn.

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Student-Driven Learning Strategies for the 21st Century Classroom, edited by Nor Aziah Alias and Johan Eddy Luaran, IGI Global, 2017, pp. 331-351. http://doi:10.4018/978-1-5225-1689-7.ch021. APA. Djoub, Z. (2017). Supporting Student-Driven Learning: Enhancing Their Reflection, Collaboration, and Creativity.Â The STEM Project Team as a Student-Developed Learning Environment: The Urgent Need for Teamwork Capability in the 21st Century Economy. $37.50. Chapter 5.Â The chapter will critically examine the evolution of pedagogy from a traditional â€˜blended learning' approach driven by classroom teaching with Sample PDF. The Evolution of Pedagogy for Non-Traditional Students at a UK Higher Education Institution. $37.50. Chapter 14. Fifth-grade students in one class had extensive experiences with learning through design during the previous year. Practice: For 10 weeks during the fall, students in both classes learned about marine biology. During this time, they also worked in teams to create marine simulations using Logo Microworlds programming and multimedia software.Â By leading with a project within a particular subject matter, be it digital stories in an English class or fraction games in a math course, programming pedagogy engages children with the potential to create "real-world" applications. This issue of equity in participation is, of course, not a new one.Â Peer pedagogy [11], or peers helping each other, is one social aspect of constructionism that has proven to help in this regard. Through collaborative learning, skills such as decision making, flexibility and problem-solving come to the fore. These skills are best developed in school, and the earlier the better.Â As a learning experience, collaboration offers a full range of models which can be adapted to suit whole-class, multi-team and small-team settings. Most importantly, an effective collaborative approach does not lose sight of the individual.Â A student is more likely to remember something learnt with and from a peer than something broadcast from the front of the classroom. The dialogue and discussion over new ideas and approaches to solving the task set make it more memorable and require a deeper level of skills. Designing learning environments to incorporate active learning pedagogies is difficult as definitions are often contested and intertwined. This article seeks to determine whether classification of active learning pedagogies (i.e., project-based, problem-based, inquiry-based, case-based, and discovery-based), through theoretical and practical lenses, could function as a useful tool for researchers and practitioners in comparing pedagogies.Â Dicha disonancia complica la diferenciaciÃ³n entre las pedagogÃas de aprendizaje activo y el recurso de la clasificaciÃ³n como herramienta comparativa ha demostrado tener una utilidad limitada. Keywords. Project-based; problem-based; inquiry-based; case-based; discovery-learning.