

# Teachers' Beliefs about Issues in the Implementation of a Student-Centered Learning Environment

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*Teachers' implementation of technology-enhanced student-centered learning environments (SCLEs) will be affected by their beliefs about effective practices. In order for student-centered programs to be used as intended, designers must be aware of the key issues that will shape their implementation and the beliefs teachers hold about these issues. This case study examined 15 teachers' beliefs about student-centered learning as they implemented Alien Rescue, a computer-based program for middle school science that was designed to create a SCLE in the classroom. Considerations for the design of similar programs are offered.*

□ Concurrent interest in learning guided by a constructivist perspective and advances in computer technology have led to a renewed interest in student-centered learning (Land & Hannafin, 2000). Student-centered learning requires students to set their own goals for learning, and determine resources and activities that will help them meet those goals (Jonassen, 2000). Because students pursue their own goals, all of their activities are meaningful to them.

A variety of approaches fit beneath the umbrella of student-centered learning, including case-based learning, goal-based scenarios, learning by design, project-based learning, and problem-based learning. Common to these different approaches is a central *question* (Jonassen, 1999) that creates a need for certain knowledge and activities. This question may be stated or implied, and can take a variety of forms, including a problem, an issue, a case, or a project. Though student-centered learning includes approaches in which this question can be determined by the student (Hannafin, Land, & Oliver, 1999), a common characteristic of the approaches listed above is that students are presented with a situation or activity which frames this central question, thereby giving learners a common goal. The central question is usually at least somewhat ill structured, meaning that the goals and constraints of the question are not clearly stated, there may be multiple justifiable responses, responses may incorporate tradeoffs or drawbacks, it is not obvious what concepts or actions are relevant to the development of a response, and learners must make and justify decisions (Jonassen, 1997). Work begins

with the presentation of this central question, and learning is the result of student efforts to develop a *response* to that question. As with the question, the response can take a variety of forms, such as a solution, an opinion, a decision, a plan of action, a design, or other product, depending on the nature of the central question.

Student-centered approaches are often defined by contrasting them with traditional instructional approaches characterized by greater teacher direction (e.g., Cuban, 1983; Hannafin et al., 1999). Key differences between the two approaches include goals, roles, motivational orientations, assessments, and student interactions, each of which is discussed in the following paragraphs.

*The goal of student activity.* In teacher-directed instruction, students work to meet the objectives set by the teacher. In contrast, in student-centered learning, students work to provide a response to a central question. Since students must sort out for themselves what they need to do and know in order to develop this response, student-centered approaches are more likely to promote student ownership over their process and learning than do teacher-directed approaches.

*The role of the teacher.* In teacher-directed instruction, the teacher sets learning objectives, and then plans a set of activities designed to help learners meet those objectives. Because learners are not assumed to be able to determine a process to meet these objectives, it is the responsibility of the teacher to guide or direct students through a step-by-step process and to make sure that any difficulties they encounter during this process are resolved. In student-centered learning, the teacher presents the central question (issue, case, problem), and then works as a facilitator as students determine the nature of the response they will develop, and then formulate and carry out a process to develop that response. Teachers help students to work through the difficulties they encounter by questioning them and helping them to identify alternative paths or resources, but they do not resolve these difficulties for the students.

*Students' motivational orientation.* T e a c h e r -

directed approaches often depend, at least in part, on extrinsic motivators, such as grades, degrees, or other rewards, to motivate students' efforts to learn. In student-centered approaches, teachers attempt to present a question that is interesting enough to motivate students to take ownership of the process of developing a response. As a result, students' actions are driven by the goals they have set for themselves rather than external rewards promised by a teacher or institution.

*Assessment.* Both the purpose and methods of assessment differ for teacher-directed instruction and student-centered learning. In teacher-directed instruction, teachers use assessments to determine grades, which in turn are used to motivate students and provide parents with information about their children's progress (Kohn, 1994). Assessment is often based on objective tests, which, Shepard (2000) pointed out, is consistent with a model of education based on a social efficiency curriculum and behaviorist theory, but which is at odds with the principles of constructivism that currently guide efforts to develop student-centered learning activities. Shepard instead recommended the use of open-ended assessment techniques that are designed to involve students in examining their own learning, focusing their attention on their learning needs and changing understanding rather than on a grade.

*Student Interaction.* The success of the cooperative learning movement (National Center for Educational Statistics, 1999) has resulted in an increase in the amount of interaction between students during teacher-directed instruction. This interaction, however, is frequently under teacher control, with teachers determining group membership, the nature of the interactions between the members, and even the role each member of the group plays. Teachers intervene in the group process when there are difficulties, and hold the group accountable for individual learning. Bruffee (1995) argued that the structure and vigilance teachers provide during cooperative learning tends to undermine students' control over their own process. Instead, student-centered approaches, which also assume a great deal of student interaction, are

more in keeping with *collaborative* learning than *cooperative* learning. Collaborative learning emphasizes students' self-governance of their interactions, allowing them to make decisions about with whom they work, and how. As students negotiate their relationships with each other, they must articulate their ideas, and engage in a disciplined social process of inquiry (Bruffee); these activities are in keeping with constructivist principles and the goals of student-centered learning.

#### Technology-Enhanced Student-Centered Learning Environments (SCLs)

The design and development of student-centered activities have largely been left to the classroom teacher in the past, but the new focus on constructivism has led researchers in the field to exploit the emerging affordances of computers in order to develop programs designed to be student centered. Programs such as Exploring the Nardoo (Hedberg, 1997), Decision Point (Brush & Saye, 2000), and Rescuing Rocky (Barab, Hay & Duffy, 2000) make use of the capabilities of technology to promote a variety of activities typical of student-centered learning, such as experimentation, research, design, and solution development. Such activities are also becoming part of commercially developed software, such as the Great Ocean Rescue (Tom Snyder Productions). Though programs such as these can vary widely in their structure and intended use, they generally provide several of the components Jonassen (2000) suggested are necessary in SCLs:

- A problem space, in which the central question that provides the focus of learners' work is presented within a context that constrains it and makes it meaningful;
- Related cases, which provide learners with descriptions of experiences they have not had themselves that they can draw on to reflect on the issue or problem presented;
- Information resources, which provide learners with access to the information they need as they work within the SCL;

- Cognitive tools, which scaffold learners as they perform tasks within the SCL; and,
- Collaboration tools, which support learners in constructing socially shared information.

Given the differences between student-centered learning and teacher-directed instruction, the implementation of these new technology-enhanced SCLs will require that most teachers make substantial changes in their classroom practices if these programs are to be used in accordance with the designers' intentions. However, both the research on teacher resistance to pedagogical change (Richardson, 1990) and the history of progressive educational reform efforts suggest that such changes may be difficult to implement. Cuban (1983) noted that, though interest in student-centered learning spanned much of the 20th century, it largely failed to take root in schools. He found "a seemingly stubborn continuity in teacher-centered instruction despite intense reform efforts to move classroom practices toward instruction that was more learner centered" (p. 160), and speculated that school and classroom organizational structures as well as teachers' own experiences as students create conditions that perpetuate traditional teacher-directed instruction (Cuban, 1982). More recently, Windschitl (2002) concluded that efforts to implement constructivist practices in schools are met with conceptual, pedagogical, cultural, and political challenges that make the transformation from teacher-directed instruction to student-centered learning practices difficult. Can technology help? Hannafin and Land (2000) argued that the impending ubiquity of powerful technologies makes the transition to student-centered learning inevitable, but the difficulties noted by Cuban and Windschitl may in fact be exacerbated by technology. Implementation of technology-enhanced student-centered programs requires that teachers integrate technology into their classes as they embrace pedagogical approaches that may be unfamiliar to them. The resistance to pedagogical change taken together with the barriers to technology integration (Ertmer, 1999) suggests that the double-barreled innovation that technology-enhanced SCLs represent may prove intimidating for teachers.

## Teachers' Beliefs

When confronted by novel situations in which they lack knowledge structures and cognitive strategies, people fall back on their beliefs to guide the decisions they make (Pajares, 1992). This may be especially true in teaching, which Nespors (1987) described as an entangled domain because of the numerous situations teachers encounter which have overlapping but not completely analogous characteristics with other situations, thereby frequently requiring teachers to make decisions in the absence of certainty about outcomes. For this reason, researchers have argued that a greater understanding of teachers' beliefs is essential to the improvement of educational practices (Fang, 1996; Lumpe, Haney, & Czerniak, 1998; Tobin, Tippins, & Gallard, 1994).

People hold beliefs about everything. In recent years there have been numerous efforts to organize beliefs into types, and examine their impact. This has led to lines of research on such topics as epistemological beliefs, or beliefs about the nature of knowledge (Schommer, Calvert, Gariglietti, & Bajaj, 1997); context beliefs, or beliefs about the responses of the people and other factors in an environment to a particular goal (Lumpe, Haney, & Czerniak, 2000); self-efficacy, or beliefs about one's capability to accomplish a certain level of performance (Bandura, 1986), and beliefs about the nature of science (Brickhouse, 1990), just to name a few. It has also led to efforts to structure the study of beliefs. For example, Rokeach (1968) posited that clusters of beliefs about particular entities and situations form attitudes and values, and that beliefs, attitudes, and values together comprise an individual's belief system. For educational research, this new interest in teachers' beliefs represents a shift away from the almost exclusive focus on teachers' observable behaviors and their correlation with student outcomes, which characterized earlier research on teacher effectiveness (Fang, 1996).

The study of teachers' beliefs is complicated by two difficulties within the field of educational psychology. First, beliefs often masquerade as a variety of other constructs, including attitudes, values, judgments, opinions, perceptions, con-

ceptions, personal theories, and perspectives. Second, researchers have offered several definitions through the years, often based on their own agendas (Eisenhart, Shrum, Harding, & Cuthbert, 1988), but the field of educational psychology has yet to reach a consensus about what the term *beliefs* encompasses. The wide variety of overlapping but not perfectly synonymous terms, combined with the range of definitions that have emerged from the literature, led Pajares (1992) to characterize beliefs as a "messy construct," one in need of a commonly held definition that can be operationalized and studied more systematically. Yet, despite these ambiguities, the study of the educational beliefs of teachers has been strongly advocated for the simple but powerful reason that teachers' beliefs guide the decisions they make and the actions they take in the classroom, which in turn have an impact on students.

Teachers implementing a technology-enhanced student-centered program are likely to rely on the educational beliefs they have developed during their experiences both as student and as teacher to navigate the process. These beliefs will shape the way in which a program is implemented, and ultimately, student outcomes. Designers who assume that teachers will conform to guidelines published in a teacher's manual, or alter their practice to fit the theoretical underpinnings that guided the design of an educational program, may find themselves seriously mistaken. For example, Guskey (1986) found evidence that in the absence of commitment to an instructional innovation, teachers often altered the practice to the point that it was no longer effective. Even teachers who are aware of the designers' intentions may disregard them if they are at odds with their own beliefs. Nespors (1987) argued that people's beliefs are far more influential than their knowledge in determining how they define problems, and that beliefs are much better predictors of their behavior. Therefore, the effective design of student-centered programs will need to take into account teachers' beliefs about student-centered learning, and how these beliefs are likely to shape their implementation of programs that are designed to be student centered.

For the purposes of the study reported here, we used a broad definition that, we believe, would be commonly acceptable: *Beliefs* are mental constructions based on evaluation and judgment that are used to interpret experiences and guide behavior.

#### Purposes of the Study

The purposes of this study were to identify key issues in the implementation of a computer-based program designed to support student-centered learning and to examine teachers' beliefs about those issues. These issues are defined as topics that teachers considered as they used a technology-enhanced student-centered program with their classes, areas of concern that teachers said would affect whether or how they would implement the program in future years, or if there were possible barriers to the use of the activity or the use of student-centered practices with the activity. The findings can help designers recognize some of the factors that can affect how teachers implement student-centered programs, which can inform the design of both these programs and professional development workshops that focus on student-centered practices. The research questions that guided this study were:

- What issues do teachers face when implementing a program that is designed to be student-centered?
- What beliefs do teachers hold about these issues?

#### METHOD

This paper reports a case study of teachers who implemented *Alien Rescue*, a computer-based program designed to support student-centered learning. The authors of this qualitative study were members of the design team for *Alien Rescue*. We have used *Alien Rescue* with middle school students for four years, conducting both formative evaluation and research with it, but prior to the study reported here, we had either performed the teacher's role ourselves or provided continuous guidance and assistance to

classroom teachers during the pilot-testing of the program. This study examines the first year in which *Alien Rescue* was implemented by teachers themselves on a large scale.

#### Participants

Fifteen middle school science teachers participated in the study; 9 of the 15 participated in individual interviews; 7 of these and 6 additional teachers participated in the two focus groups. The number of years of teaching experience of these teachers ranged from 1 to 25. Most of the teachers who participated in this study had students with special needs in at least one of their classes. These students were in special classes for part of the day, including resource, content mastery, and classes for the emotionally disturbed, but were mainstreamed for science.

Thirteen teachers had attended a training workshop on *Alien Rescue* before using it with their classes. The remainder had not. During this workshop, teachers used *Alien Rescue* the way their students would use it, while the workshop leader modeled tasks a teacher is expected to perform during the program. Teachers discussed specific pedagogical techniques that could be used to support student learning. Both the workshop and the teacher's manual for the program provided suggestions for what teachers should do in their role as a facilitator, and specific techniques they could use at various points in the program to support cognition, reflection, and collaboration.

#### Materials

*Alien Rescue* presents students with a complex problem to solve. Students, working as scientists aboard a space station, are tasked with finding new homes on worlds in our solar system for each of six extraterrestrial species aboard a spaceship in orbit around Earth. These species originated in a distant solar system that was destroyed, and after sustaining damage to their ship, entered a state of suspended animation where they must stay until they arrive on their new homes. Students must learn about the

aliens and about the planets and large moons in our solar system so as to match each species to a new home world. The program provides informational resources and cognitive tools to support learners as they develop a solution to this problem.

Students face several challenges as they work toward a solution. For example, the program contains a simulation in which students can design probes to send to other worlds in our solar system to gather missing data. Designing probes requires students to deal with a number of constraints, such as choosing the correct instrument to gather the desired data, and selecting the appropriate type of probe based on which instruments are used. An inappropriate design results in malfunctions or in a failure to obtain the needed information. Many other small problems are embedded throughout the program, such as a need to convert between the Kelvin and Celsius temperature scales, identify substances by their spectrograms, and interpret data returned from probes. The size of the overall problem as well as the numerous small challenges students encounter makes Alien Rescue complex, and students typically seek support to deal with the difficulties they encounter. However, our formative evaluation has consistently shown that students are eventually able to overcome these difficulties and articulate how they did so.

The teacher's manual for the program offers guidelines for teachers on how to implement the program so as to encourage student ownership over their problem-solving process. It also stresses the importance of the role of the teacher and strongly advocates that teachers be very active in their facilitation of students' construction of knowledge and problem-solving. An underlying assumption of our design of Alien Rescue was that the role of the teacher is critical to students' success and learning. Teachers are expected to:

- Promote the social construction of knowledge by encouraging students to collaborate with their peers, engage in peer modeling of successful strategies, and identify any flawed reasoning or missing information that could undermine their solution development.

- Help students connect science concepts in Alien Rescue to their prior knowledge; in some cases they will provide minilectures on science topics to extend student thinking and connect to other topics in the curriculum. This is normally done in whole class discussions while students share their emerging knowledge as it relates to the central problem within the program.
- Probe individual students' thinking as they are engaged in the problem so as to promote reflection and identify misconceptions. The program contains a feature to support these interactions between the teacher and individual students. In order to launch probes, students must request an authorization code from the teacher. Before providing it, the teacher can examine students' plans and question their knowledge and reasoning.

The teacher's manual contains extremely detailed suggestions on how to accomplish these tasks over the course of the program. However, Alien Rescue is flexible enough for teachers to adapt it easily to the particular needs of their students and curriculum, and this very flexibility makes it possible for teachers to disregard suggestions made in the teacher's manual or during a training workshop. Implementation of Alien Rescue is, therefore, quite dependent on the decisions of the classroom teacher.

Alien Rescue is aligned with the national standards for science education and requires approximately fifteen 45-minute periods to complete. Previous research suggests that students express greater intrinsic motivation for their work within Alien Rescue than they do for their regular class activities (Pedersen, 2003).

#### Data Sources

*Interviews.* Nine teachers were interviewed twice each by telephone: once before they used Alien Rescue with their students and once after their classes completed the program. Each interview was unstructured and consisted of two parts. In the first interview, teachers were asked about the ways they handle typical classroom activities and their definitions of and beliefs

about classroom practices relevant to student-centered learning. In the second interview, teachers were asked about their implementation of Alien Rescue; they then were questioned further about their beliefs about student-centered learning based on their experiences with this program. Questions were open ended, with additional questions used to prompt teachers to discuss aspects of the topic that they did not initiate. Sample questions from each interview are shown in Table 1. Interviews ranged from 25 to 90 min, with an average duration of 55 min. Interviews were audiotaped and transcribed. An initial round of data analysis was conducted immediately after each interview, and interview questions were revised to further examine emerging issues.

**Observations.** Approximately 25 hr of observations were conducted in seven teachers' classes. The purpose of the observations was to identify classroom practices during Alien Rescue. These observations were used as a springboard to question teachers as to their reasons for implementing the program as they did. The method used for observation was open ended in

that the researchers were in the classrooms at different periods to observe how students used the program and how teachers supported the students without any predetermined plan. The following are sample observation notes related to the implementation practices the teachers used:

This class was *very* loud and probably would have been considered out of control by many teachers, but students seemed to work better and were more interested in AR (Alien Rescue) than all classes I'd observed before. This teacher was very facilitative, not directive.

One interesting phenomenon Ms. T discussed was the collaborative spirit of the students. She noted that her students had figured out what Kelvin was by word of mouth among the groups. She had not intervened but had let them go through this process of discovery on their own and was interested to see how they came upon this understanding collaboratively.

Ms. P started with a warm-up quiz for all classes. The quiz included several questions on the board that had to be completed by all students before they could work on Alien Rescue. Interestingly, these classes were very quiet and controlled, even though they were working on the same assignments required by Ms. T the period before.

Table 1 □ Sample questions from each round of interviews.

Interview	Question
First	<ul style="list-style-type: none"> <li>• What do you see as the most important aspects of your role as the teacher in your classes?</li> <li>• Do you feel that group work is beneficial? Why or why not?</li> <li>• Are you primarily responsible for evaluating students' work? Do you feel that this is the best way to handle evaluation?</li> <li>• How do students learn vocabulary in your class? Why do you use this approach?</li> <li>• How would you define student-centered learning?</li> <li>• Would you describe your classes as student-centered? If so, in what ways?</li> <li>• Do you believe that students are capable of making decisions about what to do with their class time?</li> <li>• Do you believe that students are capable of evaluating their own work?</li> </ul>
Second	<ul style="list-style-type: none"> <li>• Do you regard Alien Rescue as a successful experience for your students? Why or why not?</li> <li>• Did you feel that students were able to use their time effectively during Alien Rescue?</li> <li>• Did students collaborate during Alien Rescue? How did that work?</li> <li>• How did you evaluate students during Alien Rescue? Why did you do it this way?</li> <li>• Did you feel that you were able to use Alien Rescue in a student centered manner? Explain.</li> <li>• Did your students enjoy using Alien Rescue? Why or why not?</li> <li>• Do students learn science content better through programs like Alien Rescue?</li> <li>• Is collaboration important during programs like Alien Rescue? Why or why not?</li> <li>• Do you see any advantages to student-centered learning over approaches with more teacher direction?</li> <li>• Do you see any drawbacks to student-centered learning?</li> </ul>

*Reflexive Journal.* This included the first author's notes about potential issues of interests that arose during data collection, early ideas about possible assertions, and methodological considerations.

*Focus Groups.* Two focus groups of teachers each met for approximately 75 min to discuss a preliminary version of the findings of this study. Teachers were presented with the assertions that had been developed based on the interviews and observations, and were asked to share their reactions. These focus groups provided a vehicle for member checking and the opportunity for teachers to build on each other's points, thereby enriching the discussion of each of the issues that arose through the interviews with individual teachers. Based on teachers' comments, some assertions were modified or eliminated because they did not adequately describe teachers' beliefs. For example, the assertion, "Student-centered learning is only appropriate for older learners," was eliminated after a focus group strongly disagreed with it and additional analysis suggested that this belief was espoused only by teachers who defined student-centered learning as an approach in which no structure or guidance was provided for students.

#### Procedures

The study was conducted over the course of one academic year, with data collection and analysis overlapping for much of that time. Data collection occurred in three phases. In the first phase, we interviewed teachers prior to their use of Alien Rescue with their classes. We noted issues that emerged from these discussions for further investigation in the second phase. In the second phase, we conducted observations in classes using Alien Rescue, and began the second round of interviews with teachers as their classes completed the program. During this phase we developed a set of assertions (Behrens & Smith, 1996) about various beliefs teachers held about student-centered learning. In Phase 3, we completed the second round of interviews and held the focus group meetings, during which we did extensive member checking in order to further

refine the assertions we had developed in the second phase.

Data analysis was consistent with the constant comparative method (Lincoln & Guba, 1985). The data were unitized; then a set of assertions was developed, and each unit of data was coded for one or more assertions. Gradually a number of categories emerged. These categories grouped one or more assertions together, which eventually formed the issues presented in the results. These categories evolved through continued data collection and multiple passes of the data, with specific units of data and assertions being recoded as the definitions and properties of each of the categories became better developed. Data collection and analysis continued until we were satisfied that the categories were saturated, meaning that additional data did not help to further define or better illustrate these categories.

Studying beliefs can be difficult because, as Rokeach (1968) argued, people are often unable or unwilling to accurately represent their beliefs. We took a number of steps to deal with this difficulty and to promote the trustworthiness of the data (Lincoln & Guba, 1985). First, rather than discussing student-centered learning in the abstract, we anchored our discussion in teachers' experiences, discussing both their regular class activities and their work during Alien Rescue. Second, we worked with 15 teachers so as to bring to light as wide a variety of opinions as possible, and to compensate for the weaknesses inherent in a process tracing methodology. To triangulate the data, we used multiple sources and methods. We conducted peer debriefing in the first two phases of the project, during which the first author presented emerging issues to the second author, who then questioned the first author in order to probe for possible biases and explore emerging interpretations of the data. Extensive member checking with the teacher participants was conducted throughout the study. Finally, we viewed the data with some caution and restricted ourselves to identifying the issues that seemed most potent to teachers as they implemented Alien Rescue, rather than attempting to identify belief systems or connections between particular patterns of beliefs and implementation practices.



We then focused our investigation on developing an understanding of the variety of beliefs held by different teachers on these issues.

## RESULTS

### Teachers' Definitions of Student-Centered Learning

A difficulty we anticipated in examining teachers' beliefs about student-centered learning was the lack of a common definition for this term. With only one exception, teachers said they were familiar with the term *student-centered learning*. Our interviews with teachers showed that our concern was valid. As shown in Table 2, four different definitions of student-centered learning emerged from the data.

Definition 1 is evocative of child-centered learning, in which teachers and schools are charged with providing developmentally appropriate educational experiences in a safe environment so as to promote the overall well-being of all students (Manning, 2000). This definition was evident in comments such as this:

I try to think of my planning as student-centered. You know, whenever I write a lesson plan, I hope that it's student-centered. I mean, I make it so that the objective is that the student will be able to . . . etc., you know. So I don't know what you mean by that because I think everything I do is student-centered.

Definition 2 suggests that some teachers view any activity in which students are active and work with their classmates as student centered. Several teachers described the science labs (activities) they teach as student centered because students use a variety of materials, work in groups, and write their own conclusions. However, the teacher typically decides which labs to use, provides students with a step-by-step process for the lab, structures students' time and format for their conclusions, and then reviews students' conclusions in class to make sure they reached the "right" ones. While students are actively engaged, most of the labs that the teachers described were teacher directed and allowed students little control over their activity, process, or outcome.

Most teachers held either Definition 3 or 4, and in a focus group, teachers agreed that stu-

Table 2 □ Teachers' definitions of student-centered learning.

Definition	In student-centered learning. . .
1	The teacher considers the interests and needs of the students in the class, and then provides instruction based on them. The teacher tries to make sure that students acquire the information and understand the concepts presented before moving on to more difficult material. The teacher takes into account individual differences and makes adjustments to accommodate individual students.
2	The teacher prepares an activity that requires students to be actively engaged. These activities are often "hands-on" and collaborative, but they do not need to be. The teacher explains the steps students need to go through in the activity, and helps to redirect students if they have trouble following the steps.
3	The teacher presents students with a complicated activity but does not tell students how to complete it. Students must figure out what to do, which means that they sometimes try things that don't work. Teachers question students about their thinking, but do not solve their problems for them or tell them what to do. When students encounter difficulties, they turn to their peers for support; therefore collaboration grows naturally out of student-centered learning.
4	The teacher presents a topic students are supposed to learn about, then allows each student to investigate whatever aspect of that topic interests him or her. This means that students are often working on widely different projects that they themselves have developed. If students have difficulty choosing what to investigate or finding materials, the teacher helps them by asking questions, but does not tell them what to do or provide a model or detailed expectations for a product. The teacher questions students about their work and students present what they learn to their classmates.

dent-centered learning was broad enough to encompass both definitions. It was useful to separate these two definitions, however, because two teachers who originally held Definition 4 had a negative opinion of student-centered learning. They believed that the lack of an established goal implied in Definition 4 made student-centered learning too difficult and potentially frustrating for students of this age:

I think student-centered learning . . . it would have to come from the students. In sixth grade, they don't know enough for it to . . . where to go look for something. Student-centered would be more for a child that's ready to take off on his own and go investigate everything. They're so basic in sixth grade. I mean, they're just learning science and a lot of the students never had such an intensive program as they're having now. And so, they want to learn, but it's a while before they can go off on their own. I do believe there is a place for student-centered learning within our curriculum, but they're not ready.

I hate it when I go to workshops and they have things on the table that make no sense and they say, "Okay, now, make a so-and-so." You know. And I watch other people and their eyes, too. You know, I never quite understood that one . . . I have no information to draw on, and all of a sudden, I'm supposed to figure this out. So, no, I usually give them some [direction] just because it's frustrating for me.

These teachers both thought Alien Rescue was effective in large part because it provided a clear goal, which helped to focus student work. Their experience with Alien Rescue seemed to have broadened these teachers' definitions of student-centered learning to include activities that, like Alien Rescue, have established goals.

Because of the varied definitions teachers held of student-centered learning, after the first round of interviews, we did not use this term in the abstract. Instead, we discussed "programs like Alien Rescue" and SCLEs like Alien Rescue." We did this in order to ground the discussion in one common experience that teachers could reflect on, and so that we could examine and compare the role of their beliefs in this one type of environment.

### The Teacher's Role

Most teachers used the term *facilitator* to describe their role both during their regular classes and during Alien Rescue. However, the activities that teachers described carrying out in this role differed somewhat. Table 3 provides a compilation of the tasks that teachers said they typically perform in each of the two settings, (a) regular class activities, and (b) Alien Rescue.

Although teachers differed in the tasks they identified, and in some cases disagreed about whether certain tasks were important, the lists in Table 3 suggest that teachers identify more tasks in which they exercise control during regular class activities than for environments such as Alien Rescue. For example, for regular class activities, several teachers said that answering students' questions and helping students who were struggling were important tasks for the teacher. For Alien Rescue, teachers talked more about asking questions to gauge student thinking and encourage reflection. As another example, though all the teachers graded students during Alien Rescue (see section on Grading below), none of them listed this as an important aspect of their role during the program, while several teachers identified this as an important task during their regular classes. While the data are too open ended to draw any strong conclusions, they do raise the question that, though teachers frequently refer to their role as that of a facilitator, what they actually do fluctuates based on the activity in which their students are engaged, and that in many cases their facilitation actually involves providing a great deal of direction and structure.

During a focus group, teachers were given the compilation of tasks teachers said they performed during Alien Rescue (as shown in the right column of Table 3), and asked to rank them in order of their importance. Two patterns were seen in their responses. First, some teachers ranked establishing checkpoints for students and checking students' work to make sure they are progressing as the most important tasks for the teacher during programs such as Alien Rescue. A second set of teachers saw interacting with students one-on-one to question their process and knowledge as the most important

Table 3 □ Teachers' activities in different settings.

	<i>Setting</i>	
	<i>Regular class activities</i>	<i>Alien Rescue</i>
Planning	Plan lessons and establish procedures for carrying out tasks during those lessons. Establish objectives. Make sure supplies are available.	Establish checkpoints or deadlines by which students must complete certain steps.
Instruction	Get students excited about science topics. Demonstrate processes. Lead discussions. Relate new knowledge to students' prior knowledge.	Ask questions about science concepts to find out how much students have learned, then provide mini-lectures on science concepts to enhance students' knowledge. Lead discussions to get students to share their findings.
Motivating Students	Praise students. Grade students to motivate them and hold them accountable for homework.	Praise students.
Behavior	Redirect students who get off task. Prevent children from being mean to each other. Prevent students who misbehave from disturbing their classmates.	Redirect students who get off task.
During Activities	Answer students' questions. Make sure students are not struggling and provide help to those who are. Make sure students practice safety procedures.	Interact with students one-on-one to ask questions about their science knowledge. Interact with students one-on-one to ask questions about their process. Encourage students to work together. Check students' work in order to make sure they are progressing at an appropriate pace. Give feedback on students' products in time for them to make revisions.

tasks for the teacher. In other words, some teachers believed that structuring the experience was the most important responsibility of the teacher, while other teachers believed supporting higher order thinking was the most important. The limited number of participants in this study makes it difficult to establish clear patterns, but this contrast merits further investigation.

#### Collaboration

Teachers generally believed that collaboration is a valuable component of any educational ap-

proach, not just student-centered learning. Interestingly, most teachers said that the reason for having students collaborate was so that they would develop skills in working together that they would need throughout their lives; they believed that complex activities such as Alien Rescue could promote the development of collaborative skills. In other words, collaboration is an end in itself; students should collaborate so that they learn how to collaborate better. For example, one teacher explained how students who were typically controlling of their classmates during group activities behaved more effectively during the program:

Just the sheer complexity of the task that they had to accomplish forced them to relinquish some of that control. You know, the controlling kids had to relinquish some of that and say, "Yeah, there's no way that I'm going to be able to do all this by myself. So I'm going to have to let them do a little bit of it." Yeah, I think it's just the bigness, I'd guess you'd say, of what they had to do that forced them into actually performing as a group, instead of, you know, one . . . one . . . one kid doing everything and the others just hanging on.

Two teachers did point out other reasons for valuing collaboration, including better problem solving through social negotiation and enhanced communication:

Just because you think it's the right idea doesn't make it the right idea. You can bounce it off others. And you can figure out, "Hey this is a good idea or not a good idea. I've never looked at things like that before. And that's why teachers get together and plan . . . We do a lot of bouncing ideas off each other. And if adults learn better that way and do a better job, why shouldn't children? And beside that, the whole idea is that they tell us . . . when they grow up they want them out on that workforce . . . you know, in their profession . . . almost all projects are done by groups of people.

And there was a lot of cross-group communication, too. They would hear, "Oh, malfunction. You know, this didn't work. This didn't work." And you'd hear one of the kids turn around and say, "Well, you can't do that. You have to do this." You know, that was pretty good, too. I like to get them to communicate with each other. And learn how to do it in a good way, in a very efficient way. In a clear way.

Most teachers assigned students to collaborative groups during Alien Rescue rather than allowing students to choose their own groups. These teachers believed that students this age would not make good collaborative choices. One teacher explained: "I just feel, knowing my kids, that I serve them better by picking their partners. With my kids and my class certain combinations are disaster."

Teachers cited two problems with collaboration. First, when the teacher pairs students of different ability or motivational levels, the higher ability or more motivated student often complains that he or she is doing all the work. Second, some students become frustrated with each other, and this interferes with their learning, though then again, collaborative activities can help students to learn to deal with these frustrations:

I had two students that were about ready to kill each other because they just didn't want to work with each other. And I told them, "well, there will be times in life we'll have to work with people that you just, you don't like them but you have to work with them."

### Grading

Almost all the teachers expressed the belief that it is essential to grade students during student-centered learning activities such as Alien Rescue. They offered two reasons for this. First, most teachers argued that grades are necessary to motivate students to do their best work, and that this incentive in turn helps students to learn more. Some students are self-motivated enough to focus and achieve without grades, but, teachers argued, other students would not be productive without grades. Several teachers said that they believed grades are only necessary to motivate students who are not self-motivated, but because the teacher must be consistent and fair, all students need to be graded.

Contrary to research findings that suggest that grading can undermine students' intrinsic motivation (Butler & Nisan, 1986; Harter, 1978), only one of the teachers interviewed believed that grading during student-centered learning could be detrimental. Teachers argued either that most students did not mind grades or that they, in fact, wanted to be graded. The latter, several teachers argued, was especially true for higher achieving students:

They were motivated to do it anyway. I think that they look at their grades, especially these higher level kids, as sort of a reward for their hard work. They want to make good grades. These kids are really into making all As.

The one teacher who did express concern that grading could undermine motivation felt this was only true for lower ability students. These students, she argued, were more likely to take risks if they believed they would not be penalized for them.

A second reason teachers offered for grading students during student-centered learning activities such as Alien Rescue was that parents and administrators expect grades and teachers have to justify the grades they give on report

cards by being able to show grades on tasks students have performed throughout the marking period. For one teacher, this, rather than motivation, was the primary reason for grading students during the program. She explained:

I wanted to give some just to have some for parents and report cards. You know, we did take some grades during this time. It wasn't paramount with me. I had enough grades before we even started it that I could have finished out the six weeks and averaged those. So it really wasn't . . . wasn't that big of an issue. I just felt it was important to have some.

Several teachers saw grades as a means by which they could establish checkpoints during the program and hold students accountable for meeting goals that they, the teachers, had set. One teacher explained:

. . . Or parts that you can check off to say, "Okay, they've done this. Okay, they're on target or where they need to be." I found that I began to say, "Okay, by Friday, you have to have at least three aliens placed or you're in trouble. And if you're not placing any more than three, that's fine. But if you are . . . you know, by Friday, you need to have that amount of placement." And I would base my grades on that.

Some teachers expressed the belief that students could grade themselves, though other teachers were skeptical. One teacher argued that while students are capable of accurately evaluating their own achievement, they hate doing so, particularly when they must support their self-assessment with evidence, as in a portfolio system.

#### Standardized Tests

One theme that emerged in the first round of interviews was the role that curriculum standards and standardized tests play in the decisions that teachers make about what topics and activities they use with their classes.

My school is totally [standardized test]-driven. We dropped a rating this year and you wouldn't believe what's going on about it, the things that are required about it . . . We are motivated by scores. The teachers aren't necessarily, but the school district's motto is your [standardized test] scores are everything. And that's not just [our district], that's the whole state.

One concern teachers raised about using student-centered activities was that they are not necessarily helpful in preparing students for standardized tests. Teachers were concerned that these tests ask specific factual knowledge questions about a wide range of topics. This presents two problems. First, teachers believed that student-centered programs such as Alien Rescue were effective in helping students to develop problem-solving skills, but that they would not necessarily be effective at helping students to learn factual knowledge. In fact, one suggestion made in a focus group was that a component be added to Alien Rescue that tests student acquisition of factual knowledge, such as a game with multiple-choice questions, so that it reflects the type of questions students are likely to encounter on standardized tests. Second, most teachers believed that for the amount of concept learning that occurs, student-centered activities are more time-consuming than teacher-directed ones. They would therefore use only a limited number of student-centered activities in a year, and be less likely to use these activities during periods when they are preparing students for a standardized test. However, in a focus group teachers discussed potential changes to the standardized tests their students would take in the near future. They had been informed that the new tests would focus less on factual knowledge and more on problem-solving. However, they remained cautious and said that this change might make student-centered activities more viable:

[Standardized tests] are gauging more factual knowledge, I guess. Or not factual knowledge, but straight facts without a connection of any sort. I think that maybe they're changing the standardized tests. They're evolving a little bit to include some critical thinking and stuff like that. But I still think you'd be more geared to the traditional memorization kind of things.

#### Student Motivation

The teachers who participated in this study generally believed that student-centered activities are likely to support intrinsically motivated behavior on the part of students. As evidence of this, teachers reported that during

Alien Rescue, students stayed engaged throughout the three-week program and were rarely off task, and that absenteeism and behavior problems were down. Several teachers also noted that students who are typically unmotivated during science were more motivated than usual. One teacher commented, "If you have a good student-centered learning project, you're not going to have any problem with motivation."

Though teachers agreed that Alien Rescue supports students in adopting an intrinsic motivational orientation, they disagreed about the reasons. Several teachers attributed student motivation to qualities of student-centered learning. For example, teachers believed that the active, hands-on nature of the program was a key to student engagement, and that establishing a goal for them to work toward helped to motivate them.

I think the reason why is because they actually had some connection to their own learning. They weren't just learning facts. They were learning the facts for a reason. They had a goal. A mission, or however you want to say it. An objective. And, I think that helped. I think that helped a lot.

Some teachers also believed that students were motivated by having control over their process:

I think they would have enjoyed the problem-solving aspect, or the aspect that they had control over their own learning, I'd guess you'd say. That they had to figure everything out for themselves. That they did have somebody there to support them and the . . . and to kind of guide them a little bit and I think they . . . they . . . regardless of whether it was paper-based or . . . or on the laptops, I think they would have still enjoyed it.

But, I think they're getting to . . . getting money . . . like cool you gave me that much money, all right! And, you know, feeling like they had control. That they were in charge of what was going on. I wasn't telling them you have to do this, you have to do this, you have to do this.

Though teachers believed that students enjoyed this control over their process, the consensus within the focus groups was that students would have been highly motivated to complete the program even if they had had far less con-

trol. In fact, two teachers who appear to have provided a fair amount of teacher direction during the program both felt that their students displayed high levels of intrinsic motivation. In general, these teachers believed that student control over their process was not an essential ingredient of intrinsic motivation.

Several of the causes to which teachers attributed student motivation had little to do with the qualities of student-centered learning. When a focus group was asked to rank order the factors that they felt most contributed to student motivation, teachers overwhelmingly ranked the reasons given above as less important than another factor: the computer-based delivery medium. Almost every teacher commented that students were motivated by the opportunity to use computers for an extended period of time. Several teachers said that the rich media and science fiction premise made students feel as though they were playing a game or solving a puzzle rather than working and learning:

Oh, because they thought it was fun. It was interesting. And it was just so novel. The idea was very original. I thought it was an interesting situation. And they just enjoyed the graphics of the program. You know it was very well done . . . I think they probably liked it more just because they liked to use the computer. And they like to use computer games.

You know, self-motivating and I think they thought it was really cool that there were aliens that we were dealing with. And we were having to find new homes for them. And you know, I think space is a big thing with this age. I think they love it. So I think all of that is what kept them so involved.

I think it's just different from what they normally do in all their other classes. I think it's rare that they have the chance to be that much in control of what they're learning, of what they're doing at any point in class.

These comments suggest that teachers believe that the delivery medium and the sheer novelty of the experience may account in large part for students' enhanced interest and intrinsic motivation. However, one teacher pointed out the problem inherent in advantages that result from novelty. When asked if she thought students would want to do other programs such as Alien Rescue, she explained:

I think the kids may even get burned out on it if it was the same kind of thing . . . Like, here's all this information in this big database and you've got to go find it. Here's your problem. That unless there was some new catch to it each time, that added one more step up or one more little thing to keep them wanting to do it. Instead of just "I've got to research this computer and write . . . recommendations." I think they would get tired of it.

#### Students with Special Needs

One of the concerns mentioned by most teachers pertained to the appropriateness of programs such as Alien Rescue for some students with special needs. Teachers described two problems that can make student-centered programs such as Alien Rescue problematic for many of these students. First, for students who read below grade level, it is difficult for them to use rich text resources independently. They are unable to find the information they need without support. Second, a few teachers believed that some special needs students do not want to take control over their learning or make decisions about their process. As a result, they will not develop ownership of the problem or task, which is considered essential in student-centered learning. They want teacher direction, and when teachers do not tell them what to do they simply remain passive or aimlessly look through program resources.

I was not successful with getting my five resource kids to own this. When their partners were gone, they did nothing. Finally, one of us would sit down beside them and start with the questions, trying to generate questions to help them. But they really just wanted to be fed . . . whatever. And it's very frustrating . . . I still do not see the kind of ownership, the kind of excitement in most of them that I do in just a regular child that's used to success.

They just didn't know . . . they wanted me to give them a rubric on, you know, go here first. Do this. Do this. Do this. Do this. They just wanted the recipe book. And since I wasn't giving that to them, that frustrated them. They felt like they were spinning their wheels. They looked there. They couldn't find anything. They looked the other place that their classmates had told them. They couldn't find anything until finally some of their friends were just giving them the answers. "This is what we did, so write this."

Though some teachers believed that student-centered learning might be less appropriate for

some special needs students than for regular education or gifted students because of these difficulties, other teachers disagreed. Several teachers said that these students had been more motivated during Alien Rescue than during their normal science classes. When asked if a student-centered approach was inappropriate for these students, one teacher replied, "No, I think they should experience whatever the . . . the other kids are experiencing. I don't want to stigmatize them or put them in a separate group. They all need to be treated the same way." Another said:

No, I think kids who have special needs . . . they're going to go away with different . . . you know maybe not as great an understanding in as great a depth as some of the more capable students, but they will get a lot out of it. They'll get some of the basic things. And then just the idea that it's motivational and maybe they will read some more than they would otherwise.

Most teachers believed that, with extra support, inclusion students could participate in student-centered activities. Teachers primarily offered supports that could be provided within the classroom, such as greater direction from the teacher, one-on-one or small group help from a special education teacher, and pairing inclusion students with regular education or gifted peers. Some teachers thought that the latter works well, though one teacher pointed out that this could lead to some resentment when the peer feels that the inclusion student is not doing his or her share. Teachers did suggest that one modification to Alien Rescue might be useful in similar programs. They suggested that audio recordings of text passages be provided for those students who have difficulty reading independently, and that the teacher be able to turn this option off for students who should read without assistance.

#### Floundering

Programs such as Alien Rescue present students with difficult problems that take a long period of time to solve. Because the problem is complex and so much information is available, some students flounder at various points in the program,

either pursuing an unproductive plan of action or failing to develop a plan of action at all. Most of the teachers who participated in this study believed that this is not necessarily a problem, and that the difficulties students encounter eventually lead them to rethink their plan of action. Some teachers pointed out that floundering may even benefit students in three ways. First, students are later able to explain why they had difficulties, and this reflection helps them to become better problem solvers. Second, students learn to deal with some of their frustrations and eventually become more self-reliant and capable of handling other student-centered activities. Finally, initial missteps give students a better understanding of the nature of scientific inquiry:

We talk in the scientific method that you sometimes don't get the right answer but you still learn something from the wrong answer. So I think that's extremely valuable. You need to see that sometimes you do mess up and you don't get what you were looking for.

These teachers generally believed that they could help students who flounder by questioning them and getting them to explain what they were doing rather than directing the students to work in particular ways.

However, not all teachers expressed this level of tolerance for student floundering. A few feared that when students flounder, they waste time or can become frustrated, and these teachers felt responsible for fixing problems that block student progress. One teacher clearly wanted to avoid programs where this may happen. She was profoundly concerned by how far afield students were able to go in *Alien Rescue*, and argued that it is necessary to establish checkpoints throughout student-centered learning activities so as to guide students away from actions she considered nonproductive. Interestingly, her concern in *Alien Rescue* was that some of the material was too engrossing:

There were just several times when they had to be refocused. "Okay, you have all that you can get from there . . ." I think it's just too new, too interesting. There's just so much cool stuff that they just have to know it all. One of the videos: they were so focused on it. They weren't ready to move on. And you kind of have to force them. "Okay, you've gotten all that you can possibly get from this."

## Community Reaction

The teachers who participated in this study believed that the adults with whom they work—administrators, parents, and other teachers—would be mostly supportive of their use of student-centered learning activities. In particular, they believed that most administrators are quite supportive of student-centered learning, and in some cases administrators even actively encourage student-centered approaches. They argued that administrators no longer expect to see students in their seats, and prefer to see students talking to each other and doing hands-on activities. However, administrators are concerned about test scores, so teachers have to be able to convince them that whatever approach they use will be effective in helping students do well on standardized tests.

Teachers also believed that most parents would be supportive of their decision to use student-centered learning activities. However, two teachers did express a concern that some parents might complain that their children were just playing rather than actually learning science, particularly if the activity were computer-based. This concern could actually discourage some teachers from using student-centered activities. When asked if she would want to use student-centered learning activities more frequently with her class than she had previously, one teacher explained:

I guess there isn't anyone who says, "You can't do this 24 hours a day, 7 days a week" but . . . I would be concerned that parents wouldn't think their kids were getting a lot out of it. Even with *Alien Rescue*, the kids kept going home and the parents would call me and say, "All he says is that he's playing on the computer." And I'd say, "Well, Ms. So-and-so, did you ask him what he was doing on the computer?" Well she didn't bother to ask him that.

## DISCUSSION

In this study, we attempted to identify some of the issues teachers are concerned about when implementing *Alien Rescue*, a computer-based program designed to support student-centered learning. We examined the key issues that emerged from the data, and teachers' beliefs



about them. Teachers are more likely to use student-centered programs in ways consistent with the designers' intentions if these programs are designed with their beliefs in mind. The issues raised by teachers participating in this study provide the grounds for some suggestions both for designers to consider as they create these programs and for professional development workshops focusing on student-centered learning.

#### Considerations for Designers

Computer-based programs designed to support student-centered learning in the classroom are still relatively rare, and the many different forms these programs can potentially take makes generalizing from our work on *Alien Rescue* to the design of other programs a task for a high degree of caution. The beliefs teachers expressed in this study have raised a variety of design considerations, but like any qualitative study, we leave it to the reader to determine the transferability of findings (Lincoln & Guba, 1985) to other situations. Given this, we would like to offer three considerations for designers that we believe are pertinent to student-centered programs: (a) Provide scaffolds for students with special needs; (b) support factual knowledge acquisition; and (c) capitalize on the multimedia affordances of computer technology to create new learning experiences for students.

- *Provide scaffolds for students with special needs.* Though teachers are accustomed to modifying materials and providing extra support for students with special needs, computers are capable of sharing this responsibility. The teachers in this study recommended one modification, the inclusion of audio recordings of text passages. However, designers of computer-based programs should explore other scaffolds as well. Some scaffolds may be unnecessary for many students, and if given access to them, these scaffolds may oversimplify students' work. Therefore, designers may want to consider allowing teachers the opportunity to select which scaffolds will be active for each student.

- *Support factual knowledge acquisition.* One

concern teachers raised in this study was that student-centered programs may not support student acquisition of the body of factual knowledge that up until now has been the focus of standardized tests. This concern has been raised previously in the literature on student-centered approaches (Williams, 1993), and teachers' comments about it here suggest that it is an issue that must be addressed by designers. Even if these tests change, teachers are still likely to judge the effectiveness of instructional materials based at least in part on how much factual information students acquire, even though this runs counter to constructivist views of learning, where learners are expected to acquire facts only as they become useful to the task at hand. Still, there is no reason why student-centered learning should not lead to factual knowledge acquisition. SCLEs are typically rich in factual information and the task presented in these environments can be designed to require the acquisition and application of many facts. However, the facts students learn in an SCLE may not be easy to assess through standardized tests. Students may not all acquire the same specific facts within an SCLE and they may be unable to apply their newly acquired knowledge to respond correctly to objective questions as used in standardized tests. Designers of student-centered programs should consider identifying a core set of facts that students should learn while engaged in the program, and provide support for their acquisition. How this is to be done without engaging students in activities that are not meaningful within the SCLE is problematic. For example, the suggestion that teachers offered in this study, that multiple-choice style questions be included in the program, is one option, but it is an awkward one. Such questions typically detach facts from contexts in which they are meaningful, which is at odds with the theoretical underpinnings of constructivism and student-centered learning. Still, this issue proved to be important enough in this study to affect several teachers' satisfaction with the program, so designers need to consider possible methods for addressing it.

- *Capitalize on the multimedia affordances of computer technology to create new learning experiences for students.* *Alien Rescue* is rich in its

use of media. The program incorporates text, graphics, audio, video, 3-D images, and animation throughout, which enhances the presentation of the program content. A consensus from the teachers in this study is that the rich media and the novel experience as created by hypermedia technology are important factors for students' enhanced interest and intrinsic motivation in using Alien Rescue. Though the development of media-rich programs is expensive, the cost may be justified by its impact on student motivation. Also, for the near future, this may mean that CD-ROMs offer a better delivery option than the Web simply because of issues associated with bandwidth and download time for rich media.

#### Suggestions for Professional Development

Our experience with Alien Rescue has suggested a need for professional development opportunities for teachers prior to their use of computer-based programs designed to support student-centered learning. Our interactions with teachers during this study offer a number of insights for the design of professional development workshops:

- *Avoid the use of the terms student-centered learning and facilitator, or carefully build a common definition with teachers.* Our findings suggest that teachers do not all define these terms in the same way. Their different definitions may lead to miscommunication and discrepancies between the teacher's implementation of student-centered programs and the designers' intentions. A better approach would be to anchor discussions of pedagogy in specific examples of facilitation strategies useful within a given program, tying these strategies to a theory of how learning occurs within the environment. Ideally, follow-up professional development workshops would be held where teachers could discuss their experiences and reflect on the nature of student-centered learning and the role of facilitator. Such discussions can help teachers link theory and practice, and figure out ways to apply their theoretical beliefs within the complex environment of the classroom, which Fang

(1996) argued should be a major goal of research on teachers' beliefs.

- *Address the many benefits of collaboration.* The teachers who participated in this study obviously valued collaboration, but primarily as an end in itself, that is, so that students develop skills for working with others. While two teachers also cited improved communication skills and better ideas as reasons for collaboration, none of these teachers talked about other potential benefits of collaboration, such as student development of an understanding of the role of collaboration in scientific inquiry, the opportunity to identify misconceptions during collaborative exchanges, or the value of peer modeling for students on both ends of the dialogue. It became apparent in these interviews that teachers had "bought into" collaboration, but did not recognize its full potential impact on learning. Professional development programs should focus on helping teachers recognize this impact and hone their skills in supporting collaboration that promotes a great deal more than just the development of social skills.

#### Future Research

Finally, a number of the beliefs teachers expressed in this study deserve further examination before suggestions about them can be offered.

- *Assessment practices.* The assumption of teachers that grading during student-centered learning activities would benefit rather than undermine motivation and learning merits further investigation. Perhaps by the time students reach middle school they have been trained to value grades, especially in a setting where they believe they are performing well. Even so, the practice may still focus student attention on working for a grade rather than learning so as to satisfy their own interests and desire for mastery. Also, grading has the potential for the teacher to retain control over student activities.

- *Factors affecting motivation.* The factors to which teachers attributed student motivation and prolonged engagement varied. Since students were all engaged in the same program across all these classes, this raises the question of

whether the reasons for their motivation varied or whether it was in fact only the teachers' beliefs about which factors were motivating that varied. Yet it is these beliefs that may have the greatest impact on how teachers choose to implement student-centered activities. If teachers believe that certain factors motivate students and that other factors are irrelevant, they are likely to promote those conditions that support motivated behavior while ignoring or perhaps even undermining conditions that they do not recognize as key factors in student motivational orientation. For example, teachers who believe that students are motivated by time on computers may skip activities such as whole class discussions, even though these discussions support collaboration and problem-solving skills. Similarly, teachers who do not believe that student control over their process is a factor in their motivation may disregard the student-centered nature of the program entirely, and direct student work. For this reason, it is essential that researchers identify both the conditions under which students are most motivated to take ownership of their work and follow through to completion, and those classroom factors that can undermine motivation, and that these findings be communicated to teachers in support materials for these programs.

- *Floundering.* By their very nature, SCLs create opportunities for students to pursue unproductive courses of action. This means that teachers must make moment-to-moment decisions about how to respond: whether to direct students, question students to help them reconsider their efforts, or permit students to pursue these paths until they recognize a need to try something different. Teachers are likely to have to make such decisions numerous times in the course of a single class. Most of the participating teachers expressed a fairly high degree of tolerance for floundering, and believed that it could benefit learning. However, considering the frequency and speed with which teachers must make decisions related to this issue, further investigation is necessary to determine if teachers' stated beliefs actually match their actions. Also, a better understanding of effective practice around this issue is needed in order to inform preservice teacher education

and professional development programs.

- *Belief systems.* The results reported here can provide some groundwork for future investigations of the relationship between teachers' beliefs, their actions while implementing programs designed to be student-centered, and student outcomes. For example, our data suggested that participants differed in which of two conceptualizations of the teacher's role they held. If patterns like this can be established and compared in terms of student outcomes, this research could help to inform preservice and in-service professional development about best practices. □

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