Contextualizing Instruction in Project-Based Science: Activating Students' Prior Knowledge and Experiences to Support Learning

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Abstract: Contextualizing instruction in project-based science involves utilizing students' prior knowledge and everyday experiences as a catalyst for understanding challenging science concepts. This study explores the prior knowledge and experiences activated during a project-based science unit in two urban middle school classrooms. A selection of contextualizing lessons was videotaped and stimulated recall interviews were conducted with target students about their thinking during instruction. Interviews were coded for the level of student thinking reported during the interview, the associated contextualizing features, and connections to science concepts, personal experiences, or real world events. Findings suggest that initial contextualizing features such as sharing personal stories and opinions were related to student thinking more about real world events, while features that foster integration such as concept maps and presentations are associated with thinking about both personal events and science together. These findings begin to identify a classification of contextualizing features in terms of the types of student thinking generated during instruction, which can inform the design of materials and professional development to foster and support contextualizing instruction in science classrooms.

Introduction

A challenge facing teachers and curriculum designers is to help students meet content standards while making meaning of science through inquiry. It is well known that students bring a wealth of personal experiences and prior knowledge to learning situations. Science educators need to consider ways to draw on these experiences to promote not only better science understanding but also develop students' capacity to apply these understandings in a variety of real world settings. Contextualizing instruction refers to the utilization of particular situations or events that occur outside of class or are of particular interest to students to motivate and guide the presentation of science ideas and concepts. This method of instruction has been promoted by national science education reform efforts as an enduring theme in their proposed reforms (National Research Council, 1996) and included as an integral part of several innovative programs (i.e., *Global Warming* (Edelson, Gordin, & Pea, 1999), *Kids as Global Scientists* (Songer, 1993)). A proposed benefit of contextualizing instruction is that it supports students' developing understanding of science concepts by bringing their prior knowledge and experiences to the forefront to be used in the learning situation (CTGV, 1992). However, little is known about how best to design and utilize contextualizing instruction in classrooms to generate and build from students' prior knowledge and personal experiences as a means to facilitate learning. In this study we explore the types of ideas and experiences activated during various aspects of contextualized project-based science instruction, and describe how this information can inform the design of contextualizing science learning environments and professional development efforts.

Characteristics of Contextualizing Instruction

There are four key characteristics identified from the literature that are common across the various attempts to contextualize science instruction. The first is the use of problems and situations that are meaningful to students. Although the situations that are at the heart of contextualizing instruction are like science tasks in intention, spirit, and problem-solving methods and thus utilize tools and thought processes that are legitimate to science, the problem situation is one that is meaningful to students in that it has implications for them outside of school (Edelson et al., 1999). The second characteristic is that the contextualizing problem or situation establishes a need-to-know situation for the learning of specific scientific ideas and concepts. The problem situation motivates a reason to learn the content and engage in the task of science learning, and provides a purpose for knowing science ideas and concepts (Kolodner, Crismond, Gray, Holbrook, & Puntambekar, 1998; Krajcik, Czerniak, & Berger, 2002). This differs from the role provided by application problems commonly used at the end of an instructional unit in that it drives the need for understanding and thus the instruction, rather than simply as a way to integrate and apply knowledge after it has been gained in a more abstract setting. Third is the use of some form of anchoring situation and event (CTGV, 1992; Marx, Blumenfeld, Krajcik, & Soloway, 1997; Sherwood, Kinzer, Bransford, & Franks, 1987) to engage students with the scientific concepts that are addressed in the problem or situation. Anchoring events provide students with a common experience from which they can relate new information. Fourth is the engagement with the contextualizing problem or situation over an extended period of time (CTGV, 1992; Marx et al., 1997). Extended study allows for analysis of the problem situation from multiple perspectives.

The Center for Learning Technologies in Urban Schools (LeTUS) has developed science curriculum materials that incorporate new ideas about teaching and learning in the framework of project-based science (Krajcik, Blumenfeld, Marx, & Soloway, 1999; Krajcik et al., 2002; Marx et al., 1997). Project-based science is an approach to teaching and learning through inquiry that embeds the pervasive use of technologies in collaborative classroom settings (Marx et al., 1997). Building from a foundation in theories of situated learning (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991), contextualizing instruction is one of the seven design principles for project-based science (Singer, Marx, Krajcik, & Clay-Chambers, 2000). Specifically, the contextualizing features in project-based science curricula are intended to embody and promote the four characteristics of contextualizing instruction in the science classroom (Rivet & Krajcik, 2002). Design features which support contextualizing instruction in project-based science curriculum materials include: (1) a driving question to introduce and organize the contextualizing theme of the project, (2) an anchoring event or experience that all students share, (3) project activities linked and woven to the driving question and contextualizing theme, (4) student artifacts or projects related to the contextualizing theme that are developed during the unit, and (5) a culminating event or experience that brings closure to the project (Rivet & Krajcik, 2002). These design features are used to guide the development of the contextualizing aspects of project-based science learning environments.

Building On Previous Experiences and Prior Knowledge

Learning is a process of building on existing knowledge (Bransford, Brown, & Cocking, 1999). However, in order to begin this process of learning, students' prior knowledge first needs to be activated. In this sense prior knowledge includes not only scientific facts and relationships, but knowledge gained through personal experiences in real-world settings and in various learning environments such as previous classroom activities. Activation of prior knowledge and personal experiences refers to cueing the memory of these earlier experiences and concepts and bringing these memories to the forefront to be utilized in the learning activity at hand. This process of activating prior knowledge and personal experiences is important in two ways. First, students may bring relevant information and experiences to the learning situation that can support the integration of new ideas. If these prior ideas and experiences are not activated, however, opportunities for capitalizing on this support may be missed. Conversely, students may also bring deep-rooted prior conceptions about scientific ideas and phenomena that may hinder the development of scientific understanding. These prior conceptions cannot be addressed in instruction unless they are first revealed by activating students' current understandings (Roschelle, 1995).

Contextualizing instruction is proposed to activate students' prior knowledge and personal experiences by engaging them in meaningful problems that establish a need-to-know situation for learning. By embedding learning in problems and situations that are meaningful for students, the legitimacy and relevance of their prior knowledge is made more transparent (Brown et al., 1989). It has also been proposed that one way to address the lack of prior knowledge held by novice learners is to embed the learning task in familiar experiences and make connections to meaningful real-world problems. This process helps the learner prepare conceptually for addressing the topic at hand as well as fostering interest and relevance in the content (Land, 2000). In project-based science, instruction is situated in settings and problems that are familiar and meaningful to middle school students. These include areas of student interest such as bike riding, issues facing their local community such as air and water quality, and issues affecting their personal health such as safety and communicable diseases.

Contextualizing instruction has also been theorized to help students make sense of complex scientific ideas, because the use of meaningful problems or situations provides students with a cognitive framework which to connect or 'anchor' knowledge (CTGV, 1992; Kozma, 1991). The cognitive framework acts as a structure upon which abstract ideas can be linked with prior understanding and fixed in long-term memory. In this way, contextualization makes the learning situation 'bushier' (Kozma, 1991) with more available links onto which students can connect ideas. Learning occurs when new information is 'hooked' and embellished by previously knowledge held in memory. Students use the ideas that they hold prior to instruction as the building blocks in an active process of linking, connecting, distinguishing, organizing, and structuring understandings of scientific phenomena. The connections made between scientific ideas and personally relevant contexts outside of school enable students to revisit the ideas and continue to build their understanding after instruction (Linn, 2000).

Contextualizing instruction focuses students' attention on the interrelationships between concepts and events. This is in contrast to more subject-specific instruction that emphasizes the presentation and recall of information but not necessarily the connections between them. Additionally, contextualizing instruction helps learners to organize and integrate knowledge by engaging students with scientific ideas from multiple perspectives while pursuing solutions to meaningful problems (Blumenfeld, Marx, Patrick, Krajcik, & Soloway, 1997). Though engagement with concepts and ideas from different perspectives, students see how the ideas are applied in different settings and build their own representations of concepts (Marx et al., 1997). Meaningful problem situations also provide learners with a perspective for incorporating new knowledge into their exiting schema, as well as opportunities to apply their knowledge (Edelson et al., 1999). Project-based science organizes instruction around large, complex problems that provide multiple opportunities for students to link their newly formulated ideas with both their prior knowledge and real world personal experiences, through the use of curriculum features such as the driving question, anchoring event, and hands-on experiences with the phenomena.

Experimental research has shown that rich contextualization features promote memory recall and subsequent transfer of information to new settings (CTGV, 1992). However, classroom-based studies about the influence of contextualizing instruction on the activation of students' prior knowledge and personal experiences have not been conducted. Further evidence is needed to understand the role that contextualized instruction can play to elicit students' prior ideas effectively as the first step toward building conceptual understandings. In this study, we address this gap in the literature by exploring the ideas and experiences activated during contextualized project-based instruction through the use of stimulated recall interviews.

Methods

Setting

This study focused on two eighth grade classrooms in urban Detroit. These classrooms were part of a district-wide reform effort in science in conjunction with the Center for Learning Technologies in Urban Schools (LeTUS). LeTUS is a joint partnership with the University of Michigan, Detroit Public Schools, Northwestern University, and Chicago Public Schools. A goal of LeTUS is to infuse the use of effective learning technologies in Detroit and Chicago schools at a systemic level. To accomplish this goal, LeTUS utilizes using a combination of custom developed project-based science curricula, learning technologies, and coordinated professional development for middle school science teachers (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000). This is accomplished through a process of building on previous educational research and collaborating closely with teachers and administrators to create sustainable reforms that address district learning outcomes (Blumenfeld et al., 2000).

The focus classes were lead by two different teachers at two middle schools in the district. One school was a public magnet school for science, mathematics, and technology, while the other was a neighborhood school. Both schools had populations that were over 90% African-American with large percentages of students participating in the free lunch program. Both teachers participating in this study were female African-Americans. Ms. Tinsley had over 20 years of teaching experience in science, and had previously worked with LeTUS project-based units in her science classroom. Ms. Holly had two years of teaching experience, and had enacted a LeTUS project-based unit during the previous school year. These teachers were selected to participate based on their prior experiences working with LeTUS project-based science units.

From each of the two focus classrooms, six students (three boys, three girls) were selected as target students to participate in stimulated recall interviews. The selection process occurred in two phases. First, students from each classroom were pre-selected with the teacher's input based on their attendance, academic performance (achieving a C grade or above in science), and being willing and open to talk with an interviewer. From the remaining group, six students from each class were randomly chosen as target students. These target students served as the focus for classroom observations, and participated in stimulate recall interviews periodically throughout the project. One target student left Ms. Tinsley's class halfway through the project after he had been interviewed twice, and his information was not included in the analyses.

Instructional Context

Students took part in a ten-week unit centered on the driving question, *Why Do I Need to Wear a Helmet When I Ride My Bike?* (Schneider & HICE, 2001). This question led students through an inquiry into the physics of collisions, focused the concepts of motion, velocity, acceleration, and force. In addition, the driving question situated the project in a context familiar and important to many students, that of riding a bicycle and falling off. Three events anchored the project. First, students shared personal stories about bicycle accidents they have been in or heard about. The second was a video on bike safety where a young boy talked about his accident when he was not wearing a helmet. The third was a demonstration of an egg riding in a cart down a ramp. When it reached the bottom, the cart hit a barrier and the egg flew and broke on the tabletop. The event created drama for the students and provided a useful scenario to discuss the several important science concepts related to collisions. This demonstration was also the focus of the final artifact, where students created and investigated a helmet for the egg to demonstrate their understanding of collisions. Students created an initial concept map of their understanding of a collision at the beginning of the unit, and answered a set of four questions about their understanding of the egg and cart demonstration. These artifacts were revisited and elaborated multiple times over the course of the project, as the students' understanding of the science behind a collision developed.

Data Collection and Analysis

This study focused on selected contextualizing lessons from the *Helmet* project. These were ones in which the contextualizing features of the instruction played a dominant role. Such lessons included the introduction to the project and the anchoring events; the set-up to benchmark lessons and inquiry activities that established a need-to-know situation for student learning; the wrap-up to these lessons where students integrated what they learned with what they already knew and related back to the contextualizing problem or situation; and the culminating event of the project where students further integrated and applied their knowledge to address the overall contextualizing problem through artifact development and presentations. In all, 10 contextualizing lessons (11-12 class periods) were observed for each teacher. The videotaped observations were focused on all students during whole-class discussions and demonstrations. During small group work, observations rotated amongst groups that included one or more target students in the attempt to observe each target student in small group settings an equal amount of time.

Stimulated recall interviews with target students from each classroom were conducted shortly after each lesson (Gass & Mackey, 2000; Winne & Marx, 1982). While videotaping, particular classroom episodes that might serve as the focus for the stimulated recall interviews were identified and recorded. The selected episodes included: a) the teacher review of previous lessons, b) the teacher gives explanations of how ideas relate to the driving question, c) the teacher gives directions to be thoughtful ("think about this"), d) students working on thoughtful tasks (i.e., integration or brainstorming), or e) students sharing their thoughtful work (i.e., stories, presentations, or discussions). Focus episodes were between 1-4 minutes long and were selected from the beginning, middle, and end of class. A total of 8-10 minutes of tape was selected for review during each interview. Within each focus episode, moments were identified to pause the tape and ask students what they were thinking about at the time. These moments included: a) after teacher gives directions to be thoughtful ("think about this"), b) after the teacher reviews or refers to the driving question, egg and cart demonstration, or video, c) after the student listens to a response from a classmate, d) after the students gives an answer in class, e) after the student starts written work/small group discussion, and f) if the student shows an affective response during the interview to an event on the tape (e.g., talking, grinning, etc.). Students were also able to stop the tape and share their thinking at any time. Two target students were interviewed individually within an hour after each target lesson, with each target student interviewed 3-5 times over the course of the semester. Overall, a total of 43 stimulated recall interviews were conducted.

Stimulated recall interviews were transcribed and embedded in detailed classroom descriptions at the points during the lessons that served as the stimulus for students' comments. The interviews were then coded by segment. An interview segment was defined as both the classroom event that served as the stimulus and the student's response to that event. Each interview segment was first coded as to the contextualizing feature or classroom event discussed in the stimulus portion of the classroom videotape, which included the driving question, accident stories, reasons for not wearing a helmet, bike accident video, the egg and cart demonstration, concept maps, development of the final egg helmets, and final presentations. Second, each interview segment was then coded for the cognitive level of students' comments in terms of content-focus (thinking of science ideas or other experiences related to class), task-focus (thinking about what was going on in class), off-focus (thinking that is off-task or not cognitively related to class events), affect (emotional response to the episode), or not applicable (no response/can't remember). Reliability of this coding scheme was checked by another researcher, with an agreement rate of 88%.

In addition, comments that received a 'content-focus' code were further categorized by the types of ideas and experiences students reported thinking about in conjunction with the content at that moment during instruction. These student comments are of particular interest in this study, because they reveal the ideas and experiences that students brought forth to the learning situation while participating in contextualizing instruction. The three categories related to 'content-focus' comments were: a) thinking about personal experiences or real-world events (e.g., "I was thinking about a major accident I had, I fell and cut my leg"); b) thinking about other contextualizing features or prior classroom episodes (e.g., "When everybody's just naming what they think they should do, and I was just mainly thinking that we should just do the driving question, why is it best for us to wear a helmet?"); and c) thinking about specific science concepts (e.g., "I was writing that Newton's first law applies to what we were doing because when the cart was in motion it wanted to stay in motion until the brick was there and stopped it"). The results of coded stimulated recall interviews were then tallied across interviews for each target student and across all target students in terms of the rating category for each interview segment and the contextualizing feature that served as the stimulus focus for the interview segment. Percentages of the number of comments for each code as compared to all comments were calculated. Comparisons were made first between the overall level of comments by teacher, and then by the type of content-focus comments made in relationship to each contextualizing feature.

Findings

Overall

The first analysis considered the percentage of students' comments that were coded as content-focus, as compared to comments coded as task-focus or off-focus. The coded responses from each interview segment were tallied across the interviews for each target student, and aggregated across students. The percentages of responses for each cognitive level category as compared to all comments made during the interviews were determined. Figure 1 presents the results of this analysis, organized by teacher.

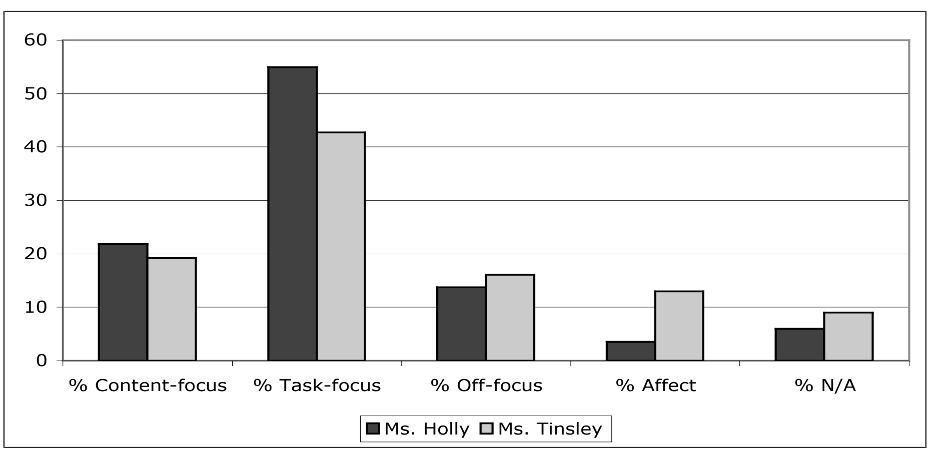

Figure 1. Percentage of students' comments in each category

As can be seen from Figure 1, the most frequent rating category for the comments made by students was 'task-focus'. This indicates that for the most part, students reported thinking about what was going on in class. This included thinking about the activity or investigation they were doing, attending to the teacher's comments or class discussion, and considering their response to a question or event. Relatively few comments received a rating of 'affect', which indicated students reporting an emotional response to a classroom event. It is interesting to note that across all of the student interviews, 46.3% of the episodes that were rated as 'affect' involved students giving presentations to their peers of their responses to the four questions, their concept maps, or their final egg helmet designs. In these comments students expressed a range of emotions, from nervousness before they began, relief and joy when they were finished, frustration or disappointment that they could have done better, to pride and confidence when they felt they did a good job during their presentations.

About 20% of the total number of student comments were coded as 'content-focus across the stimulated recall interviews. Students' content-focus comments were further categorized by reported thinking about personal experiences or real-world events, thinking about other contextualizing features or prior classroom episodes, and thinking about specific science concepts. Figure 2 presents the percentage of content-focus comments in each of these three areas made by target students in terms of the total number of coded comments regarding each contextualizing feature, organized by personal/real world connections.

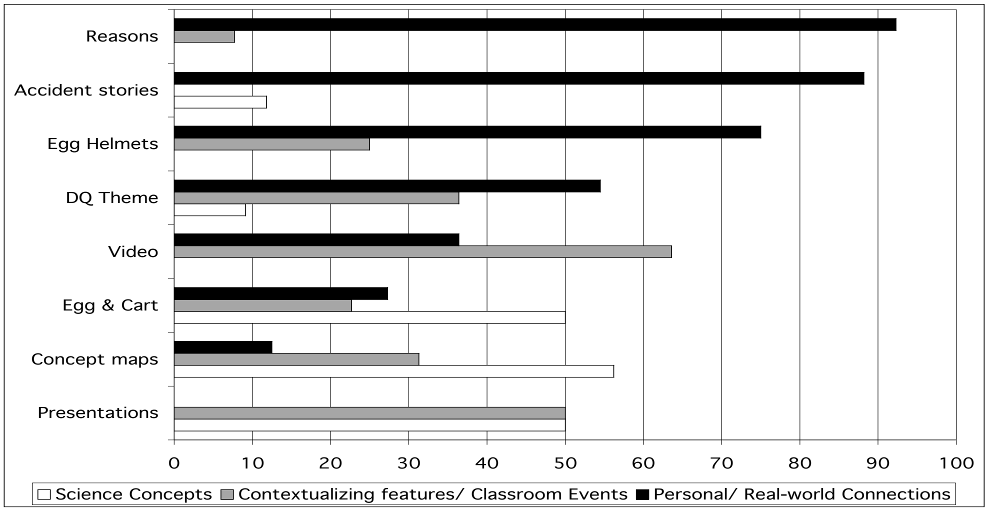

Figure 2. Comparison of the percentage of 'content-focus' comments in each category by contextualizing feature

These findings begin to indicate ways in which the contextualizing aspects bring forward students' ideas and experiences to be used in the learning situation. For example, it can be seen from figure 2 that personal accident stories, reasons for why students did not wear bike helmets, and the final egg helmet artifact strongly elicited student thinking of their own personal experiences and real-world examples. Similarly, it appears that the video, as well as the driving question and concept maps to a lesser extent, are associated with students thinking about other contextualizing features or classroom events. This analysis also indicates that while the egg and cart demonstration, concept maps, and final presentations elicited the lowest percentages of student comments in relationship to thinking of their personal lives or real-world examples, these were also the same features that elicited the highest percentage of student comments in relationship to thinking about particular science concepts.

Classification of Contextualizing Features by 'Content-focus' Comments

The results of these analyses can be used to describe and classify how contextualizing features influence the types of students' ideas generated during instruction. This classification can be used to inform the design of future learning environments.

Generating student thinking about personal experiences and real world examples: The contextualizing features that were the most closely associated with students' thinking about their personal experiences and real-world examples were the personal accident stories and discussions regarding the reasons that students do not wear bicycle helmets. These events also generated the largest percentage of 'content-focus' student comments during the interviews. Both of these events involved students thinking about experiences related to them personally or others their own age, which may have been the reason for this result. Similarly, the development of egg helmet designs also was associated with students' thinking about real world examples, in particular the design and functioning of real helmets. However, this feature generated a greater percentage of 'off-focus' comments. This indicates the need to further support student thinking about the real world examples associated with the final artifact during instruction.

Generating student thinking about other contextualizing features and prior classroom events: Several contextualizing features were associated with student thinking regarding other curriculum features and prior classroom events. The strongest association appeared to be related to the teachers' use of the video as a reminder of earlier events during subsequent lessons. When the video was brought up, students reported thinking back to the events and demonstrations shown in the video, and class discussions about it. Although only a few 'content-focus' comments were made regarding the final presentations, this feature also appeared to be related to student thinking about related contextualizing events. This may have been a result of the requirement by both teachers to relate the presentations to earlier demonstrations and investigations. Student thinking in this area appeared to occur primarily as a result of the teachers' activation of prior classroom events during instruction. Further consideration should be given regarding additional ways to support students' thinking of related contextualizing features or prior classroom events through the design of investigations, demonstrations, or small group activities.

Generating student thinking about science concepts: Students' thinking with regards to the science concepts presented in the unit were associated with several contextualizing features, including the driving question, the personal accident stories, the egg and cart demonstration, the concept maps, and the final presentations. For example, as the project progressed students began to use science concepts more often and accurately to describe their observations of the egg and cart demonstration, or to elaborate on their personal accident stories. It is interesting to note that the most comments regarding science ideas involved the integration activities that were revisited periodically throughout the project, such as work with the concept maps, the four questions related to the egg and cart demonstration, and the final presentations. This indicates that these features were used successfully during instruction to bring forward students' science thinking, and points to the need for learning environments to focus students' attention further on the use of these contextualizing features as a means to support learning.

Generating student thinking across areas: The three contextualizing features that were associated with student thinking in each of these areas were the use of the driving question and contextualizing theme, the egg and cart demonstration, and the concept maps. They appeared to be the most frequently reoccurring features used throughout the project enactment, and served as points to connect and integrate the different aspects including the science concepts and the real world setting. The design of learning environments should incorporate and accentuate these features further to support student thinking in these areas. It is also important to consider how the other contextualizing aspects could be supported and utilized in a similar manner to these features in order to support student thinking more consistently across the extended project.

Conclusions

This study looked the types of ideas and personal experiences activated during contextualized instruction as part of project-based science. Although this was a small sample and only focused on one curriculum unit, the findings begin to inform us about the type of thinking that occurs in urban classrooms through attempts to contextualize science instruction and the role that particular contextualizing features have to support the activation of students' prior ideas and develop integrated understandings. This study begins to identify specific aspects of contextualizing instruction that appear to especially bring forward students' personal experiences, prior knowledge, and recollection of previous classroom events to the learning situation (Edelson et al., 1999; Linn, 2000), and inform an initial classification to describe the ideas associated with each feature and the role they should play in future curriculum design. For example, integration activities such as the design and revision of concept maps were associated with students' frequent reports of thinking about particular science concepts and related classroom events, indicating the utility of these multiple opportunities for students to integrate and apply science concepts. These findings further inform project-based curriculum design and professional development efforts (Fishman, Marx, Blumenfeld, Krajcik, & Soloway, in press) to contextualizing science instruction by providing an initial framework to guide the selection and use of particular contextualizing features throughout extended projects in order to most effectively support student learning of important science concepts.

This study provides initial evidence to indicate the importance of particular contextualizing features and their role during instruction of an extended project-based science unit. It is still unclear from this study how these features interact across the extent of the curriculum to support student learning of science concepts and their relationship to the contextualizing theme. It may be possible that over time students come to view the connections between these anchoring events and particular science concepts through multiple exposures and representations of this relationship. The analysis points to the need for further exploration of the role each aspect of contextualizing instruction may play, both individually and in concert, to support student learning.

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