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Feature Article

Setting Sail or Missing the Boat: Comparing the Beliefs of Preservice Elementary Teachers With and Without an Inquiry-Based Physics Course

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We examined the beliefs about science teaching and learning held by elementary preservice teachers in a science methods course, comparing students who had experienced an inquiry-based physics course with those who had not. Students who had taken the physics course prior to the methods semester were better equipped to recognize and learn from inquiry and better able to apply an inquiry approach to their lesson planning. Students who were concurrently enrolled in the physics course began to revise their incoming beliefs about what it means for students to be active learners in science. The students with no experience in the inquiry-based physics course maintained their limited view that science teaching should be "fun," with the teacher as teller and fun-maker.

Introduction

As science teacher educators, we often ask ourselves the question that every teacher or teacher of teachers has asked before: "Why don't they understand this?" Although our students use pedagogical jargon accurately, we often have the sneaking suspicion that they are missing the boat when it comes to understanding and accepting an inquiry-based approach to science teaching. How do we convince them that the island upon which they stand is actually a volcano that is ready to explode at any moment? After all, this island is their home: a paradise of lay theories, of teaching traditions, of perceived stability.

In response to this concern, Abell and Smith (1994) recommended, "We need to portray richer images of science to preservice teachers in their science content courses. They need experiences inventing their own explanations and dealing with anomalous data and alternative explanations" (p. 485). In the fall of 2000, a new physics course was introduced at our institution. It was specifically designed to help elementary education majors experience the essential features of inquiry—questions, evidence, and explanations (National Research Council, 2000).

We wondered if students who took this new course would approach their work in the elementary science methods course any differently. That question led us to the present study.

Purpose of the Study and Theoretical Framework

The purpose of this study was to examine the beliefs of preservice elementary teachers about science teaching and learning in the context of an elementary science methods course. In particular, we wanted to compare at several points throughout the elementary methods course the beliefs of students who had experienced the inquiry-based physics course with those who had not.

This study is grounded in the research on teacher beliefs. According to Calderhead (1991), preservice teacher beliefs can be characterized in four ways. First, students of teaching come to our courses with strongly held beliefs that have been built over years in the apprenticeship of observation (Lortie, 1975). Secondly, their beliefs are often in stark contrast to what teacher educators hope to elicit in the teacher preparation program. Third, the link between practice and belief is problematic. For any number of reasons, enacted teaching is never completely consistent with stated philosophy. And finally, preservice teachers and their instructors differ in expectations for learning. All of these factors influence how students make sense of their teacher preparation experiences. Richardson (1996) claimed that, because incoming beliefs strongly influence what and how teachers learn, beliefs must be a focus for instruction in teacher education.

Many theorists agree that beliefs are created in the process of enculturation into a certain group and endure unaltered unless deliberately challenged (Lasley, 1980). According to Pajares (1992), the earlier teachers' beliefs are in place, the more resistant to change they become. In the case of elementary education majors, many of whom have wanted to be teachers since they were children, beliefs about teaching and learning have developed over many years. Preservice elementary teachers bring their negative attitudes about science (Tosun, 2000) and their transmission views of learning (Black & Ammon, 1992) into the teacher education program. Beliefs can persist even when, logically, they should not. Since each new experience is filtered through the lens of prior belief, individuals may turn conflicting evidence into support for their beliefs (Nisbett & Ross, 1980). Thus, the problem for teacher educators is to challenge firmly held beliefs that are often in conflict with the best practice literature. However, we must exercise caution. If we consider that a beginning teacher's sense of identity is closely tied to his or her understanding of what it takes to be a good teacher (see Volkmann & Anderson, 1998), any attempt to challenge these beliefs may be taken as a direct and personal attack.

Researchers in science education consistently have demonstrated the relationship between beliefs and instruction. A number of studies have employed Ajzen's (1985) Theory of Planned Behavior to analyze the influence of science teacher beliefs on teaching intentions. For example, Haney, Czerniak, and Lumpe (1996) found that teachers' beliefs toward standards-based science instruction significantly contributed to behavioral intention. Beck, Czerniak, and Lumpe (2000) similarly found that teachers' beliefs impact their intentions to implement constructivist science teaching strategies. Other researchers, using case study methodologies, likewise have noted a connection between beliefs and practice. Smith (2003) compared the cases of two elementary teachers of science and described how they translated their beliefs about science learning into instruction. Zipf and Harrison (2003), in a study of two Australian elementary science teachers, found that beliefs about science teaching influenced their teaching practices. One implication of these studies is that preservice teacher education "may be the most timely period to provide opportunities for students to establish favorable beliefs regarding the nature of science teaching" (Haney et al., 1996, p. 987). Unfortunately, according to Loughran (1994), "many preservice teachers complete their teacher education programs without confronting their beliefs about such things as teaching and subject matter" (p. 366).

Preservice elementary teachers typically predict that their future teaching performances will be above average (Weinstein, 1989)—based on their interpersonal skills rather than pedagogical or content knowledge. Gunstone, Slattery, Baird, and Northfield (1993) found that elementary education majors chose affective characteristics, including having rapport, enthusiasm, and the ability to inspire students, over more cognitive characteristics to define a good teacher. Such beliefs run counter to the teacher education view that building pedagogical content knowledge is the prime role of teacher preparation (see, for example, the National Science Teachers Association, 2003, *Standards for Science Teacher Preparation*). Thus, we can predict some conflict for students when course goals focus on teaching for understanding rather than on motivating and inspiring students.

In our work, we have been developing profiles about student beliefs in the context of the elementary science methods course. We have found that preservice teachers come to us with strongly held beliefs about the nature of science (Abell & Smith, 1994; Abell, Martini, & George, 2001), as well as about science teaching and learning (Abell, Bryan, & Anderson, 1998; Bryan & Abell, 1999; Martini & Abell, 2000). Our students believe that knowledge exists in the world and that students, like scientists, must receive or discover it. They want to use hands-on lessons with their students so that students will enjoy science, but they believe that either before or after students use materials, teachers should tell the answer. They believe it is the teacher's responsibility to make sure that every student receives the correct answer (Abell et al., 1996).

Although studies of teacher beliefs about inquiry and of their inquiry practices abound, the connection of science teacher beliefs about inquiry with their science content experiences has received scant attention in the research. Stofflett and Stoddart (1994) found that "learning science content through conceptual change methods facilitated the development of understanding and use of conceptual change pedagogy in teaching practice" (p. 31), although in this case the science content instruction took place in the context of an elementary science methods course. Skamp (2001) claimed that preservice elementary teachers in Canada formed their images of good science teaching based on their experiences in undergraduate science courses, as well as from science methods courses. There is some evidence that reformed science courses at colleges and universities make a difference. In the Arizona

Collaborative for Excellence in the Preparation of Teachers, evaluators found a positive relationship between the number of reformed content courses taken by future middle and secondary science teachers and their reform-based teaching practices as beginning teachers, as measured by the Reformed Teaching Observation Protocol (Judson & Sawada, 2002).

From a situated learning perspective, we could say that, although preservice teachers are newcomers to the community of practice of elementary science teaching, they are actually old-timers as members of the school science culture (Lave & Wenger, 1991). We agree with Putnam and Borko (2000), that "an important part of learning to teach is becoming enculturated into the teaching community—learning to think, talk, and act as a teacher" (pp. 9–10). The discourse community we establish in the science methods course is one that helps students recognize their beliefs about science teaching and learning; confront evidence that may be in conflict with those beliefs; and, in the best of all worlds, revise their beliefs in light of the evidence (Abell & Bryan, 1997). We wonder what role an inquiry-based experience in a science content course plays in enculturating future elementary teachers into the science teaching community.

Research Questions and Methods

The following research questions guided this study: How do preservice teachers view science teaching and learning on entering an elementary science teaching course? How do the beliefs of students who have experienced an inquiry-based physics content course differ from the views of those who have not? In what ways do the beliefs change after experiencing a month-long moon inquiry in the elementary science teaching course?

In the fall of 2000, one section of a new course, Physics 290E, "Physics for Elementary Education," was offered to 23 elementary education majors at our institution. The following semester, when our study took place, two sections of Physics 290E, enrolling about 50 students total, were offered. The new physics course was designed around an inquiry-based framework using the American Association of Physics Teachers (1996) "Powerful Ideas" curriculum. This curriculum employed a conceptual change approach (Hewson, Beeth, & Thorley, 1998), with each series of lessons involving a cycle of finding out ideas (students are asked to respond to a question and compare their responses to their team's), making observations (students participate in a variety of hands-on tasks), and making sense (students discuss models and invent concepts in teams and in the large group to account for observations) (for more information about this course, see Abell, Smith, & Volkmann, in press; Volkmann & Zgagacz, 2004). The course was taught by a science education faculty member with a background in high school physics teaching, not by a physicist.

Our study took place in two sections of the elementary science methods course, EDCI 365, taught by Hubbard during the spring semester, 2001. Of the 40 students enrolled, 4 were male. Four of the methods students had taken Physics 290E the previous semester, 9 were concurrently enrolled, and 27 had no experience with the physics course.

Data sources for the study included a beliefs questionnaire and key student written products from EDCI 365. Hubbard administered a researcher-designed beliefs questionnaire during the second week of the course that consisted of open-ended items concerning beliefs about science teaching and learning, the roles of teachers and students, and goals for elementary students. Additionally, all students took part in a month-long investigation of the moon (see Abell, George, & Martini, 2002). Students kept a daily moon journal of their observations, questions, and explanations. In their final journal entries, students wrote about their current understanding of phases of the moon, how it differed from their incoming ideas, what they believed about teaching and learning about the moon, and how they would carry out such an investigation in their own classrooms. This journal was another primary data source for this study. During the tenth week of class, students interviewed children about their science ideas pertaining to a science topic that they would later teach. The written product of these interviews described the children's science ideas, compared them with the scientific view and the research literature, and included a plan for how to carry out future teaching based on the evidence gained in the interviews. This interview paper was a third primary data source. Hubbard's anecdotal records of in-class discussions written after class served as a secondary data source for the study.

The data were analyzed inductively, through constant rereading of the data sources, looking for patterns of beliefs among the students. We selected six cases that represented a range of experiences with Physics 290E and a range of responses to the beliefs survey for deeper analysis. We then performed both within and across-case analyses in order to interpret the data. The findings are based on these six cases.

Of these six students, two—Elizabeth and Audrie—had not taken the physics course prior to enrolling in the elementary science methods course, two—Valerie and Brenda—were concurrently enrolled, and two—Stacy and Kayla—had taken Physics 290E the semester prior to the methods course. Elizabeth was selected because she admitted at the start of EDCI 365 that she had very little science background and was uncomfortable making claims about best science teaching practice. Audrie, on the other hand, had taken a non-inquiry-based physics course the previous semester and would provide insight into experiences with different types of science content courses. Valerie and Brenda, both concurrently enrolled in Physics 290E, represented very different methods student profiles. On the first day of class, Valerie informed the instructor that she did not like science and was not good at it. Brenda, in contrast, was enthusiastic about science teaching and learning from the outset. We were interested in examining their thinking throughout the semester. Kayla was a dedicated student who consistently asked for clarification about ideas and assignments. She mentioned early in the methods course that she had been frustrated with Physics 290E because it was difficult to gain the clarification she needed. Stacy, a nontraditional student, informed Hubbard at the beginning of the semester that she did not like the inquiry approach due to her frustration with Physics 290E. These students would help us understand the role of Physics 290E in forming beliefs and knowledge in the methods course setting.

Findings

We have divided this part of the paper into three sections to communicate our findings from the three primary data sources: the beliefs questionnaire, the moon journal, and the interview paper. Each of these data sources sought to gain a different perspective on student beliefs and provided unique data about them.

Inspecting the Boat Before We Sail: Incoming Beliefs

At the beginning of the methods course journey, we surveyed students about their science teaching and learning beliefs. Student answers to the beliefs survey during this semester were typical of students from past semesters (see Abell et al., 1998). The words *hands-on* and *active learner* appeared in almost every answer. The idea that science ought to be *fun* above all was commonplace; seldom did students mention that a goal of science education would be for students to understand science concepts. They frequently mentioned that children should *discover* things (see Abell & Smith, 1994) and that teachers should not use textbooks or lectures. They provided little reasoning to support these views—other than that using a discovery, hands-on approach with no textbooks or lectures would be more fun.

Elizabeth and Audrie, with no Physics 290E experience, fit into this mold. Elizabeth said that the role of students was to "gain knowledge through discovery" and the role of the teacher was to "teach science as interesting." She believed that the reason teachers should use a hands-on approach was so that students would enjoy science more and have a better visual representation:

> I believe in a 'hands-on' approach to science. I feel that students need to get their feet wet to really enjoy science. In my classroom, there will be stations and labs that students will participate in. Through this method of learning, students will get a visual representation of science.
>
> (Elizabeth)

Audrie's responses represented a focus on the affective qualities of a teacher. When asked to describe good science teaching, she said, "An understanding teacher who cares about the students in and out of class." She believed that, in a good science lesson, the teacher would "explain things through visuals or activities and take time to thoroughly explain things—make you feel less overwhelmed." Audrie believed that good science teaching involves a warm, pleasant environment. Despite her comment that children should be active learners, it appeared that she believed the teacher's role is to make sure that students are comfortable by transmitting information clearly. Like Elizabeth, she thought that the role of hands-on science was motivational: "I always liked hands-on science myself. I thought this was not only a great way to break the monotony of always having to read or write papers, but we could actually work with our hands."

Valerie and Brenda, who were concurrently enrolled in Physics 290E, displayed an array of beliefs. Valerie mentioned that an outstanding teacher "understands how every student feels about learning science and tries to create activities that fit everyone's needs." (Remember that Valerie had entered the methods course with a negative attitude toward her own science learning.) Valerie, like most of the other students in the class, stated that students should do "hands-on activities and be active learners, not just read the textbook and answer questions," and that they should be "active and excited." The teacher's role is to pick topics that are interesting and make learning science a "great experience." Unlike other students, Valerie was able to provide a more detailed picture about what this great experience might look like:

> Science should be full of experiments, observations, investigations, and active student involvement. Students should have plenty of opportunities to work in groups and present their own findings about investigations . . . . The teacher should not be giving the students the answers all of the time; science should be discovered and revealed through experiments and real-life activity.
>
> (Valerie)

Valerie's answers reflect both affective and cognitive goals for science teaching – where students have fun and are excited, but also present the findings of their investigations.

Brenda, too, reported a more detailed perspective on science teaching than most of the methods students. She mentioned that teachers should not include reading a textbook and answering worksheet questions in a good science lesson, emphasizing the need for hands-on learning to give the children a change to be "actively involved." She indicated that the role of student is that of explorer, and the role of teacher is guide:

> My role as a teacher in science is to guide my students in the right direction for their learning needs; however, I feel that the students need to be given much freedom and individual or even cooperative responsibility so that meaningful learning can be accomplished. I often think that, if as an elementary student, I would have been able to discover something on my own . . . then I would have learned more and would appreciate science more.
>
> (Brenda)

Brenda's answer demonstrates that her science goals go beyond students having fun to include meaningful learning, although her methods are still a bit unclear. In the cases of Valerie and Brenda, we wondered to what extent they came to the methods course with these ideas and to what extent they were beginning to change their inquiry vocabularies based on their beginning experiences in Physics 290E, the methods course, or both.

Stacy and Kayla, who had previously taken Physics 290E, wrote answers to the beliefs survey that represented more complex understandings of science teaching than their classmates. Stacy explained that she "hoped to be more of a guide than a leader" in her classroom so she could continue to learn herself. Several students mentioned that as teachers they would be "lifelong learners," so in and of itself Stacy's answer is not unique. However, her explanation of the student role is revealing: "Students are learners, yet they also act as teachers or guides when working in cooperative groups in science. They should not only learn through discovery, but also through other students." Stacy also indicated that one of her goals would be to help students see that there can be several ideas about science and not everyone has to agree immediately. Because working in small groups and debating ideas were explicit strategies of the Physics 290E course, it appeared that Stacy had appropriated these ideas from Physics 290E into her views of science teaching and learning. Stacy never mentioned fun as a reason for using a certain teaching methods, nor did she state that hands-on learning qualified as good science teaching.

Kayla, from the first day of the methods course, portrayed herself as a perfectionist who carried a high level of stress as a student. In her response to "what is good science teaching?" she specifically cited her experiences in Physics 290E, as well as her personal frustrations as a learner:

> I have to confess that I did not like walking into my Physics[290E] classroom, doing an experiment and leaving without a definite answer to the scientific questions I was trying to find. I experienced many days of frustration. I was used to being given the answers and learning the bold-faced words in my science textbooks. Experiments were sometimes included in my elementary classrooms, but I always left with the teacher giving me the definite answer. Dr. V. did not do this. He often would ask, 'What do you think?' I wanted to say, 'I don't know. If I knew, I would not have to ask, and I would feel like I was accomplishing something.' Why was he doing this? Does he know that I am already stressed out? Dr. V. knew my frustrations. He knew what I was thinking, but he wanted me to see science from a whole new perspective, and it is that view that I believe constitutes good science teaching.
>
> (Kayla)

Kayla was in the midst of a struggle to define good science teaching. She stated that teachers should allow students to do their own investigations and arrive at their own conclusions, but that teachers should likewise "alleviate students' frustrations" and be "caring and encouraging." Kayla was trying to balance her quest for getting right answers with the inquiry-based strategies of Physics 290E. She appreciated those strategies in the abstract, but had been personally frustrated by them as a learner.

The two students in the study who had taken Physics 290E provided answers in the beliefs survey that went beyond a surface accounting of science teaching and learning. Rather than claim that science teaching should be hands-on, they described the role of students as learning science through other students and as using evidence from their own investigations to develop explanations. They expressed the need for students to test their own ideas and build understanding together. They were in the midst of struggling to connect their learning experiences in Physics 290E with their visions of science teaching and learning. We were interested to see how their visions would develop throughout the methods course.

Swabbing the Deck: The Moon Investigation

There comes a point in our science methods course when it is time to get down and dirty—to challenge students' existing ideas about science teaching and learning. This first happens when we enact a month-long investigation about the moon (Abell et al., 2001, 2002; Martini & Abell, 2000). The major artifact from the moon study, the moon journal, is an excellent source of data about student understanding of phases of the moon and students' science teaching beliefs. During the semester under study, the moon journals illustrated typical patterns of frustration about the length and depth of the study and about student struggles to understand. We also gained insights into student thinking about inquiry-based science instruction.

Elizabeth and Audrie, the students who had not taken Physics 290E, continued to focus on fun as the primary benefit of inquiry, and they sought ways to make the moon unit more fun and less *boring* for their students. Elizabeth stated that she would change the unit by teaching it in the fall or late spring so that the students would be more likely to see the moon (January and February had been overcast often that semester). She also planned to select one person from each small group to record data for the entire week:

> Each student would get his or her own turn to observe and record the moon data. I feel that this would be a good method because the students would not have to record data every day and get bothered or fed up with this activity.
>
> (Elizabeth)

Elizabeth and Audrie indicated that they would approach the moon unit differently in elementary school by answering more questions directly in their teacher roles. In their final moon-journal entries, both stated that the moon investigation had been "fun," and that enjoyment was the main reason to employ a long-term investigation. Despite the fact that each mentioned she had learned more than she had ever expected to learn from the moon study, the focus on the affective was foremost. Thus, the students who were not involved in Physics 290E continued to focus on fun as a primary benefit of inquiry, and they planned to make instructional units more fun and less boring for their students.

During the moon investigation, Valerie and Brenda, concurrently enrolled in Physics 290E, began to make connections between how they were learning science and how they would like to teach it. By the end of the moon unit, Valerie expressed a shift in attitude toward science and inquiry learning, with her previous distaste for science giving way to enthusiasm about inquiry:

> I was worried about how much you expected us to know. I did not know anything at all about the moon. I was also worried because I was unable to see the moon for a period of time, and I was wondering how I was going to learn anything. I was not really interested in learning about the moon; but, as time went on, I realized that I had a lot of questions about it, and I enjoyed figuring out the answers. I am excited to do this type of inquiry in my classroom.
>
> (Valerie)

Valerie acknowledged that she had more to learn, but she was satisfied with her progress. She also recognized that the entire class had moved forward together in their understanding. Her answers reinforced her earlier idea that both the affective and cognitive sides of science teaching and learning are important.

In her moon journal, Brenda also expressed enjoying the freedom to ask questions and propose solutions. She discussed the value of having students argue the merit of their solutions based on the evidence of their investigations. It was Brenda who first questioned the rest of the class when they proposed the explanation that the phases of the moon were caused by the Earth's shadow. Although she did not have a better explanation, she pointed out the flaws in the shadow theory. A period of chaos emerged as the class searched for a better theory. Brenda continuously referred to this event in her journal, claiming that feelings of personal worth came as a result of being allowed to argue about ideas. She repeatedly stated that she believed children could accomplish the same thing. In class, Brenda shared the ways in which the moon investigation followed the same pattern of instruction as her Physics 290E course. Thus, the preservice teachers who were taking Physics 290E concurrently with the methods course were beginning to make connections between how they were learning science in Physics 290E and in the moon investigation, and with how they would like to teach it.

Stacy and Kayla, the students who had already taken Physics 290E, believed that their frustrations in studying the moon was understandable and expected and, therefore, more openly discussed frustrations with the moon investigation than some students. Stacy wrote, "When our class was assigned this moon-journal project, I thought it would be another pointless, boring task. Wow! I was completely wrong. I'm hooked on watching the moon, and my family now watches for it too." She explained how her ideas changed when she discussed ideas with her classmates:

> Even though there were times when I was totally frustrated about this project, a positive outcome has been that I have been able to clear up some of my misconceptions. Although I learned about the moon's phases and its revolution around the Earth (too many) years ago in school, it seems like that was just rote memorization of facts. My learning was superficial until this project.
>
> (Stacy)

When she described how she would carry out a similar unit in an elementary classroom, Stacy's ideas were very different from Elizabeth's, focusing more on the learning than the fun. Instead of having students observe less frequently, as Elizabeth had suggested, Stacy opted for more data collection and science talks (Gallas, 1995) to keep students involved:

> It's important for students to make daily observations of the moon so they can collect data and share their ideas with others. Of course, in an elementary class, I would have the opportunity for daily moon talks. This would help the students get a better idea of what's going on and keep them focused, even on the days they couldn't see [the moon]. After students observed the moon for a few weeks, I would ask them to make predictions about what the moon will look like the next day or the next week. Through group discussions and science talks, I would ask productive questions to see if students could find a pattern in their observations. I would have resources available for students to investigate questions they have and manipulatives so they could test their ideas.
>
> (Stacy)

Interestingly, this dialectic procedure of observing and discussing resembled both the moon investigation we enacted in the methods course and the conceptual change teaching strategies of Physics 290E. Science talks (Gallas, 1995) and productive questions (Elstgeest, 2000) were concepts introduced in the methods course after being modeled in Physics 290E.

Kayla also discussed her frustration during the moon investigation, frustration arising mainly when she was unable to see the moon due to the weather. After the class discussed the fact that no one had been able to see the moon lately, Kayla's journal entries became less troubled. However, she continued to worry when, at the end of a class period, she could not articulate what she had learned. Kayla was uncomfortable with science talks when the instructor did not step in and tell the class the correct answer. In one journal entry, she related that it was difficult to know if her classmates were correct or not, even if what they said made sense. However, by the end of the moon investigation, Kayla did find closure, and she stated that she would encourage students because, "even when they felt like they were not getting anywhere, they would figure things out by the end of the investigation." Although Kayla did endorse inquiry-based science teaching in her final moon-journal entry, her journal indicates some mistrust of the approach.

Stacy and Kayla knew that frustration was going to be part of science learning in an inquiry setting, but also realized that meaningful learning would result. They were able to make sense of what they had learned from the perspective of a student and propose teaching methods that were more detailed and more aligned with reform documents than the other students.

Hoisting the Sails: Planning Science Instruction

Later in the methods course, the preservice teachers interviewed children to ascertain their conceptions about a particular science topic and then wrote a paper about their findings. In this paper, they connected their interview findings to planning a unit of instruction that they would team teach in a local classroom later in the semester. At this point in the course, they were getting closer to being able to sail into classroom science teaching.

Elizabeth's group interviewed fifth graders about their understandings of sinking and floating. They found that most of the students thought that large objects would sink and small objects float. In teaching a lesson on sinking and floating, Elizabeth planned that she would first explain the scientific answer to the students. "I would explain the scientific evidence behind this and bring in a picture of the inside of a cruise ship so students can understand how it can stay afloat." She did not mention allowing students to propose explanations or providing opportunities for testing, despite her statement at the beginning of the semester that hands-on science is best. She did mention that students should explain their ideas to others, but only after she had given them the scientific explanation:

> If my students totally understand [the cruise ship] and I want to challenge them, I would ask them to explain their reasoning to others. I would like them to educate their peers on the subject. This working relationship would benefit both groups, and it would also be a collaborative activity.
>
> (Elizabeth)

Elizabeth's statement displays a lack of understanding of collaborative work and of the purpose behind students sharing ideas. She did not see sharing as an opportunity for the social construction of ideas, but only as a way to reiterate the teacher's explanation.

Audrie planned to teach a lesson about insects to second graders, so she interviewed students concerning their ideas about insects. In response to the misconceptions she found, she planned to show students a large picture of ants and list all the parts:

> I will then explain to them the names of the different parts of the ant. Together we will count the number of legs and segments. We then as a class could do the same thing with another insect. Afterwards, we will circle the characteristics that are the same. Hopefully this will help clarify characteristics of insects for the students. Then, I will have the students cut out of construction paper ant parts and construct an ant.
>
> (Audrie)

Audrie's plan, like Elizabeth's, was to start with a teacher-led explanation. Rather than having students derive patterns from a number of instances of insects, she planned to tell the parts and then label them in other examples. Her ending activity, to make a construction-paper ant, focused on having fun, not challenging student thinking.

Valerie, concurrently enrolled in Physics 290E, intended to teach an insect lesson to kindergartners with her team. Valerie's plan, in sharp contrast to Audrie's, started with an investigation:

> I would want to bring in a few different types of insects, and have the students compare and contrast things about the insects. Hopefully, the students would derive answers like insects have six legs and three body parts. After the students have had a chance to look at insects and other types of bugs to compare and contrast them, then students can learn more from reading books, completing other investigations, creating their own insects, discussions, and any other insect learning activity.

Valerie was able to define inquiry on an appropriate level for kindergarten. She designed a lesson that allowed students to induce patterns from observations. Reading books was offered as a means to extend the investigation, not as a way to present the right answers.

Brenda, also concurrently enrolled in Physics 290E, planned a shadow lesson for a kindergarten class based on her interview findings. In her interviews, she found that children did not understand how moving an object away from or toward a light source would affect its shadow. Some children believed that a shadow smaller than the actual object could be made if the light source was close to the object. Brenda credited her Physics 290E class for helping her think about how to address these misconceptions:

> In my Physics 290E class, the same thing occurred. Many students thought this same thing, and our instructor simply did an "experiment" where he projected a light onto a wall. He then held up a small block at approximately the halfway point from the light source to the wall. He moved the object both close to the wall and close to the light for our class to see what happened to the shadow as he did this. We were able to see that, no matter what he did, it was not possible to make the shadow smaller [than the object]. We also were able to find out what needed to be done to make the shadow larger and the same size as the original object. I think that this type of guided exploration could definitely be done with the students in this case.
>
> (Brenda)

Brenda also mentioned the need for students to explore and understand that shadows are all around them and indicated that such an exploration might be an appropriate starting point. Brenda did not mention the need for the lesson to be fun, but, instead, demonstrated ways to challenge students' nonscientific ideas. Both Brenda and Valerie, in contrast with Elizabeth and Audrie, focused on student thinking in their lesson plans.

Stacy, who had taken Physics 290E, prepared to teach a plant lesson in first grade with her team. Because her interviews uncovered students' lack of understanding about plant-growing needs, Stacy planned a lesson where students would conduct various tests on plants.

> I know that most of them think that plants need soil and water to grow. I hope to introduce an experiment with plants growing in various mediums, such as water, soil, sand, and baggie gardens, to help them learn what plants need to grow.
>
> (Stacy)

Stacy indicated that she did not want to start with a lot of scientific explanations, as that might represent an "informational overload" to first graders.

Kayla and her partner Kyle, who also had taken Physics 290E the prior semester, were scheduled to teach a food-groups lesson to first graders later in the semester. Through their interviews, they found that students did not have any set rules for categorizing foods. For example, some students placed cookies in the fruit category. Kayla and her partner decided that it would be best to start their lessons by helping students look for patterns in the data. They proposed an inductive process where student thinking would be central. They planned to start by "bringing in a wide variety of fruits and vegetables [students] may not have seen or heard of." Then students would come up with "rules about each food group that would help them when they find foods that are unfamiliar to them." Kayla and Kyle indicated that they would help students in this process, not by giving the scientific explanation before the activity began, but by facilitating students as they built explanations.

In their approaches to lesson planning, each of the preservice teachers demonstrated underlying beliefs about science teaching and learning. Elizabeth and Audrie revealed a belief that students need a scientific explanation at the start of a lesson. Stacy disagreed, claiming that such an approach would lead to information overload. Kayla and Valerie exhibited the belief that even young students can compare and contrast objects and recognize patterns without a scientific explanation coming first. Brenda displayed a belief that teachers can challenge student thinking with a discrepant event rather than with an explanation.

Elizabeth and Audrie, the two students with no Physics 290E experience, planned to teach units where the main concern was that students would have fun. If any misconceptions arose, the teachers planned to "erase" them through telling and then move on. When they taught their units later, they restricted opportunities for inquiry and were frustrated when students did not all reach the same ideas.

The students concurrently enrolled in Physics 290E planned very different kinds of units. Their plans showed more attention to students sharing of ideas and working together to build understanding. Brenda credited her teaching ideas to the Physics 290E class. "In my Physics 290E class the same thing occurred . . . . I think that this type of guided exploration could definitely be done with the students in this case." Because Brenda, as a learner in Physics 290E, had experienced a new view of science teaching, she was able to envision inquiry-based instruction for kindergartners.

Stacy and Kayla, who had already taken Physics 290E, were further along the journey of translating their experiences into instruction for elementary students. They proposed an inductive instructional process where student thinking would be central. In a unit on nutrition, Kayla planned to start by "bringing in a wide variety of fruits and vegetables [children] may not have seen or heard of." From this experience, she predicted that students would come up with their own rules about the food groups. Stacy's and Kayla's plans included investigations and reading, but the reading was to follow the investigations, much as it had in Physics 290E.

Discussion

The students who had taken Physics 290E prior to the methods course seemed better equipped to recognize and learn from inquiry when they experienced it and better able to apply an inquiry approach to their lesson plans. From the start, both Stacy and Kayla referred to their experiences in Physics 290E when defining good science teaching in writing or in class discussions.

Once the moon investigation was underway, Stacy and Kayla discussed personal frustration in learning science through inquiry. However, both students employed their beliefs about teaching by using inquiry and their experiences in Physics 290E to make connections between "good science teaching" and the ways they were learning science. Before the moon investigation, Stacy believed that it was good to challenge students, but not to frustrate them. After the moon investigation, she recognized that some frustration was inevitable if students were going to play the role of scientist. Stacy's belief in the role of students as teachers created a comfort zone for her during the moon investigation, where she was willing to try to figure out answers to her own questions. She also applied this belief to her first grade lesson, where her team allowed considerable discussion among students. The first graders asked questions of each other and worked together on solutions before Stacy provided much guidance.

Kayla equivocated more than Stacy. Kayla attributed her frustration in Physics 290E and during the moon investigation to her desire to know what was expected of her and her desire to get good grades. Her personal frustrations with inquiry made it difficult for her to employ inquiry strategies with children, even though she believed inquiry represented best practice in science teaching. Her solution to this inner conflict between the good and bad of inquiry was to plan science inquiry lessons, but be prepared to alleviate student frustration by cautioning them that they would be frustrated and confirming that such frustration was "okay." In her teaching, Kayla made use of student discussion in cooperative groups and put students in charge of figuring out answers when classifying food groups. Despite their frustrations, Stacy and Kayla were prepared to set sail into inquiry-based science teaching by the end of the methods course. They entered the methods course with more comprehensive beliefs and expectations about science teaching than their peers; they deepened their convictions about inquiry and improved their practices throughout the course.

Valerie and Brenda, who were concurrently enrolled in Physics 290E, entered the methods course with such priorities as student enjoyment through activity-based lessons. After just a few weeks, both were questioning what it meant for students to be active learners. Brenda questioned her own education and wondered if she could have learned more had she been allowed to investigate her own ideas in school. Valerie's moon journal revealed that she found out she was not "bad at science," as she had proclaimed the first day of class. By the 10th week of the methods course, she had begun to apply inquiry techniques in her planning of the insect unit.

That is not to say that Valerie and Brenda were ready to go to sea unassisted. They did not completely understand, nor were they ready to use inquiry in their teaching by the end of the methods course. Despite Brenda's initial plan to begin the shadow unit with a discrepant event, her group planned a lesson for a kindergarten class that started with a demonstration and the scientific explanation for shadows. Their plan for the second lesson was for students to explore shadows with objects and flashlights. When asked why they did not allow students to explore and question first, the group seemed puzzled. Brenda expressed conflict between wanting students to investigate and wanting them to "get it." This was similar to the conflict she was experiencing in Physics 290E.

Elizabeth and Audrie never claimed to agree with the practice of inquiry in science teaching. We believe they missed the boat we were readying for them throughout the methods course. They saw the role of teacher as teller. Their main concern was for students to have fun, and this could be accomplished while maintaining the teacher as teller role. As a result, they never perceived any discrepancies in the methods course to challenge their beliefs. Although for many students the moon investigation is a discrepant event that challenges their science teaching beliefs (Martini & Abell, 2000), that was not the case with Elizabeth and Audrie. They preserved their original beliefs by focusing on the fun aspects of the investigation rather than the learning potential.

Elizabeth's group switched from their sinking and floating plan to a fifth-grade unit on the human skeleton. With prodding from Hubbard, they decided to ask the students to construct a skeleton (using paper bones) before showing the students the correct construction. They were shocked when students were not able to correctly assemble the skeleton. The fifth graders explained how they built their skeletons and argued until the class came to consensus. The class was a bit loud at times, and several groups talked simultaneously. Hubbard, who was observing the instruction, noticed that some groups were rearranging their skeletons based on the information presented by their classmates. However, the preservice teachers interpreted the noise as losing control of the class. In her reflection on the lesson, Elizabeth wrote that she would not spend so much time letting students share their skeleton ideas and argue over which ones were correct. Most likely she would expend her energy in making lessons more fun, while telling students the correct arrangements.

While Audrie's plan did take student misconceptions into consideration, she believed she could "erase" the misconceptions by telling students the facts up front. She wrote, "Misconceptions are important to take care of before you begin to teach your lesson. This allows you to understand more clearly where they are coming from—start with a clean slate." Furthermore, erasing misconceptions would make room for fun: "Clearing up misconceptions makes teaching a lesson like insects more enjoyable for everyone, if everyone has the same understanding." Audrie wanted to clear up misconceptions to make the lesson more enjoyable, not because she thought it would create more meaningful learning. Her focus on the affective made it difficult to create a space for the cognitive.

Gunstone et al. (1993) listed five possible outcomes of the introduction of new teaching and learning ideas into teacher education:

> Ideas may be: simply rejected; misinterpreted to fit in with, or even support, existing ideas; accepted, but the teacher cannot apply them in another context; accepted, but lead to confusion; accepted, and form part of a coherent long-term personal view of teaching and learning. (p. 51)

Several teacher education studies confirm this assertion (Abell et al., 1998; Holt-Reynolds, 1994; Stofflett, 1994). The present study, as well, supports the Gunstone et al. categories. We would classify Elizabeth and Audrie as rejecting or misinterpreting the intents of the methods course and the other students as somewhere along the acceptance spectrum. However, based on our findings, we offer two additional possible outcomes. Preservice teachers may verbally accept ideas as being good teaching practice when teaching children, but not believe they, themselves, should learn in the same manner, making complete acceptance at some future time problematic. Kayla represented such a position. And, secondly, preservice teachers may accept their instructor's ideas temporarily so that the teacher educator in turn will accept them as students (see also Abell et al., 1998). We really have no way of knowing to what degree our students' responses indicated their actual visions of teaching or to what extent they were merely playing the good-student role.

Conclusion

We have often experienced frustration as science teacher educators when students seem to miss the boat in accepting inquiry. To partially remedy the situation, we thought we needed to change their experiences of didactic science courses. The findings of this study indicate that students who have taken an inquiry-based science course in their teacher preparation programs may be more ready to consider inquiry teaching and learning for elementary students and may have a clearer vision of how to make that happen. Taking part in a new school science culture characterized by inquiry can help break the strongly held beliefs about teaching and learning characterized by Calderhead (1991) and Pajares (1992). A needed next step is to follow these students into their beginning years of teaching to see if the actions they take on these newly formed beliefs are sustainable as newcomers in the community of teachers.

We believe that, if instructors of science methods courses collaborated with instructors of inquiry-based science-content courses, they could deliver consistent messages about inquiry and help students draw connections among courses. We are not claiming that every student who took Physics 290E benefited in the same ways or to the same degree as the participants in this study. We are not claiming that one course alone can reverse years of experience with didactic science teaching. Yet, it is possible that, if we developed several of these inquiry-based science content courses for our preservice teachers, the cumulative effect would be that future teachers would be better prepared to accept and apply inquiry teaching upon leaving the science methods course. If we continue to listen to our students of teaching, they can help us develop best practice for science teacher preparation.

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