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ABSTRACT

This study was undertaken to examine prospective elementary teachers' learning about science inquiry within the context of an innovative life science course developed specifically to meet the unique needs of elementary education majors. As part of the course, prospective teachers not only engaged in an extended science investigation, but also participated in a project designed to support elementary school children in experiencing inquiry-based science. The literature indicates that such experiences can have a powerful influence on teachers' developing understanding of science learning and teaching. In light of this, the research questions for this study are: (1) What do prospective elementary teachers learn about science inquiry within the context of the course?; and (2) In what ways do their experiences learning to do science inquiry influence prospective elementary teachers' understanding of science and science learning and teaching? (Contains 51 references.) (SAH)

# Engaging in Science as Inquiry: Prospective Elementary Teachers' Learning in the Context of an Innovative Life Science Course

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This study was undertaken to examine prospective elementary teachers' learning about science inquiry within the context of an innovative life science course developed specifically to meet the unique needs of elementary education majors. As part of the course, prospective teachers not only engaged in an extended science investigation, but also participated in a project designed to support elementary school children in experiencing inquiry-based science. The literature indicates that such experiences can have a powerful influence on teachers' developing understanding of science learning and teaching (Boardman, Zembal-Saul, Frazier, & Weiss, 1999; Dana, Boardman, Friedrichsen, Taylor, & Zembal-Saul, 2000; Smith & Anderson, 1999; Zembal-Saul & Oliver, 1998). In light of this, the research questions for this study are: (1) What do prospective elementary teachers learn about science inquiry within the context of the course? (2) In what ways do their experiences learning to do science inquiry influence prospective elementary teachers' understanding of science and science learning and teaching?

### THEORETICAL UNDERPINNINGS

Contemporary reform efforts in science education emphasize the importance of children learning science as inquiry (American Association for the Advancement of Science, 1990; National Research Council [NRC], 1996). In particular, the National Science Education Standards (NRC, 1996) call for the centrality of inquiry in science learning:

The *Standards* call for more than "science as a process," in which students learn such skills as observing, inferring, and experimenting. Inquiry is central to science learning. When engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. In this way, students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills. (p. 2)

The importance of inquiry in science learning is not a new idea in science education (Schwab, 1962; Trowbridge & Bybee, 1990). As alluded to in the quote above, however, inquiry traditionally has been addressed through the teaching of "science process skills" or "skills of a scientist," such as making observations and inferences, often in the absence of concept development. In contrast, the Standards suggest that the reform vision of science inquiry lies beyond the "processes of science" approach. Moreover, scientific inquiry is identified as a

“controlling principle in the ultimate organization and selection of students’ activities” (NRC, 1996, p. 105). This renewed emphasis on a more authentic approach to science inquiry in the classroom unveils serious issues regarding the preparation of teachers. In its report, Shaping the Future, the National Science Foundation (1996) asserted that all undergraduate students, including prospective K-12 teachers, “...should be presented with an opportunity to understand what science is, and is not, and to be involved in some way in scientific inquiry, not just hands-on experience” (p. 2). Unfortunately, the reality is that most prospective teachers have never been engaged in learning science as inquiry or exposed to effective, inquiry-based instruction. How, then, can we expect them to support children’s science inquiry in a manner consistent with the vision of reform?

One of the aims of teacher preparation is to assist prospective teachers in developing pedagogical content knowledge (PCK). Shulman (1986, 1987), who first conceptualized the construct of PCK in the mid-eighties, contended that teaching for understanding is a complex cognitive activity that requires the transformation (Wilson, Shulman, & Richert, 1988) of teacher knowledge from diverse domains, including subject matter knowledge, pedagogical knowledge, and knowledge of context. In other words, PCK is that knowledge which is unique to making particular subject matter more comprehensible to others (Grossman, 1990; Shulman, 1986, 1987). While in and of itself subject matter knowledge is insufficient for teaching for understanding, the role of robust subject matter knowledge is seen as central to developing PCK and teaching for understanding.

Research findings in a number of disciplines indicate that prospective teachers have limited PCK (Borko & Livingston, 1989; Borko & Putnam, 1994; Feiman-Nemser & Buchmann, 1986, 1987; McDiarmid, 1990; McDiarmid, Ball & Anderson, 1989; Putnam & Borko, 1997; Wilson et al., 1988). Given that PCK requires the transformation of subject matter knowledge for the purposes of teaching, one possible explanation for prospective teachers’ difficulties with PCK is their inadequate subject matter knowledge (Borko, Eisenhart, Brown, Underhill, Jones & Agard, 1992; Cochran & Jones, 1998). Studies in science (Clement, 1982) and mathematics (Ball, 1990) suggest that most education students do not have basic knowledge of their disciplines as they begin their teacher preparation programs. This interferes with their ability to develop powerful representations of content designed to promote understanding among learners (Ball, 1990).

To date, the emphasis in science teacher preparation (Zemal-Saul, Blumenfeld, & Krajcik, 2000) has been on what Smith (1999) refers to as pedagogical knowledge of teaching substantive aspects of scientific content, where substantive knowledge refers to central concepts and principles within a discipline and how they are organized. With this focus, issues associated with syntactic aspects of PCK are overlooked. That is, consideration of pedagogical knowledge associated with the nature of science and norms of scientific work are omitted. As mentioned previously, most prospective teachers have not had opportunities to engage in science inquiry as learners, not to mention develop understandings of the nature of scientific knowledge and the purposes of scientific investigations (Smith & Anderson, 1999). Given that contemporary reform efforts in science education (NRC, 1996) emphasize the content and processes of science, there is a compelling need to help prospective teachers develop more robust understandings of the discipline – both substantive and syntactic aspects.

A number of approaches have been attempted to assist prospective teachers in developing richer and more integrated understandings of science and scientific knowledge for the purposes of teaching. Some of the more successful approaches reported in the literature include content courses developed specifically to meet the needs of prospective teachers (Boardman et al., 1999; Dana et al., 2000; Zemal-Saul & Oliver, 1998) and teacher preparation courses and/or programs that emphasize developing understandings and abilities associated with teaching science for understanding (Marion, Hewson, Tabachnick & Blomker, 1999; Zemal-Saul, Starr, & Krajcik, 1998). Such an innovative science content course provides the context for this study in which we examine prospective elementary teachers' learning about science inquiry.

### **CONTEXT: TEACHING WITH INSECTS**

Teaching with Insects (TWI) is an applied life science course designed specifically for prospective elementary teachers by a team of faculty and graduate students from Entomology and Science Education. It resulted from the continuation of a prior collaboration (Boardman, et al., 1999) that also aimed to assist prospective teachers in developing science content knowledge by using insects as a vehicle for exploring life science concepts and modeling reform-oriented pedagogy.

TWI is one of several half-semester, one-credit courses, known as tracks, that can only be taken after the successful completion of the core course, Introduction to Entomology. Other tracks have been developed for specific majors, such as field crops entomology and management of insect pests of ornamentals. The two-credit core takes place during the first half of each semester, while the tracks are scheduled during the second half of the semester. Basic entomology concepts addressed during the core include internal and external anatomy, structural diversity, behavior, natural history, and integrated pest management. During the semester in which the prospective teachers in this study took the course, the professors were highly interactive and contextualized the material in real-life experiences that reflected the nature of science. Course assignments were designed to be interesting and engaging. For example, in one instance students were asked to write obituaries for pesticides. For another assignment, students were required to write a paper describing how they navigated across campus using the behavioral taxes of insects. In addition, professors used multimedia during lectures and made supplemental information available on the web.

Teaching with Insects was designed as an application of concepts developed in Introduction to Entomology and had two main components – a science inquiry project and a teaching component. We began by giving the prospective teachers a culture of insects that was used for both aspects of the course. The first task was to identify the insects in their culture and keep them alive for the remainder of the semester. As a long-term project, prospective teachers worked in small groups to design and conduct science investigations (i.e., inquiry projects) based on questions they developed about their insect cultures.

Prospective teachers met two class periods per week, and in each session the instructors focused on particular aspects of scientific investigations and experimental design -- making observations and crafting testable questions; designing experimental tests; identifying and controlling variables; collecting, analyzing and interpreting data; posing data-based explanations and communicating results and implications of research. An additional aspect of the science inquiry project was to have prospective teachers identify the intersections between what they were doing in their inquiry project and what the National Science Education Standards (NRC, 1996) were promoting as important to children's science learning.

A secondary course theme was to explicitly attend to scientists' work and how aspects of scientific practice could be represented in children's science learning. During most class

sessions, connections were made to school and children's science. For example, when discussing testable questions in science we also emphasized productive questioning (Harlen, 1985) that encourage children to identify and ask testable questions.

The teaching component of the course included multiple opportunities to interact with children in a guided environment. The experiences advanced the prospective teachers through three phases. In the first phase, they were engaged as learners in model lessons that were designed to be developmentally appropriate for children. In second phase, children were engaged in those lessons but the course instructors assumed the role of teachers. During this phase, prospective teachers were co-learners with children and focused on children's ideas about insects and life science concepts during instruction. In the final phase, the prospective teachers assumed the role of teachers. In small groups, they modified and adapted their long-term investigations into inquiry-based lessons for children following a Predict-Observe-Explain model. The lessons were taught during "Hands-On Bugs Day," a public outreach event sponsored by the Entomology Department.

Prospective teachers were prepared for this experience through a plan-teach-reflect model. During the planning phase, the prospective teachers worked in their small groups to develop age appropriate lesson plans about concepts related to their inquiry investigation. They consulted and identified intersections with the National Science Education Standards (NRC, 1996) and engaged in a peer teaching experience prior to the Hands-On Bugs Day. The actual teaching experience followed an open format where children and parents cycled through the various lessons. The teaching phase of Hands-On Bugs culminated with an opportunity for prospective teachers to share and reflect upon the experience through written reflections and discussion.

## METHOD

The study was framed within a qualitative case study design (Creswell, 1998; Maxwell, 1996; Merriam, 1998; Yin, 1989) that was used to drive the collection, organization, and analysis of the data. The multiple case study approach was descriptive and interpretive and sought to examine each group as a case. Eleven prospective elementary teachers who were enrolled in the pilot semester of Teaching with Insects served as participants in the study. They ranged in status



from freshman to seniors. Of the eleven students, one was a white male and all others were white females.

A case study involve an array of data sources in order to build an in-depth picture of the case (Creswell, 1998). Multiple sources of qualitative data were collected as part of this study. These data included audiotaped open-ended, semi-structured, pre/post course interviews, videotaped class sessions, participant-generated course projects (e.g., lesson plans, reading reactions) that were posted to an electronic bulletin board, web-based threaded discussions, and field notes. The interviews served as the primary source of data. The initial interview took place prior to the first class meeting for all but one of the participants. All post-course interviews were conducted during the final week of class. The primary focus of the pre-course interviews was to elicit participants' conceptions of science and doing science. In addition, background information about participants' experiences as learners of science was gathered. The final portion of the pre-interview focused on school science and issues of learning and teaching. Participants were asked to revisit their elementary school science experiences and discuss important aspects to consider for use in their own classrooms. The post-course interviews were intended to track change over time; therefore, many of the same questions were revisited. On occasion participants were asked to respond to statements they had made during the pre-course interview. Given that much of the course was devoted to learning about science inquiry, participants were explicitly asked to comment on science inquiry during the post-course interviews.

In this study, the stages of analysis involved collecting and analyzing data from several cases. Within-case and cross-case analysis used analytical induction techniques (Goetz & LeCompte, 1984) and attempted to build abstractions and explanations across the cases. Trustworthiness was developed through the use of multiple data sources, triangulation of data from multiple sources, and the use of counterexamples to the assertions (Mathison, 1988; Maxwell, 1996). Cross-case analysis resulted in emergent themes associated with prospective teachers' developing understanding of science, scientific inquiry and science teaching and learning within the context of an innovative life science course. The themes were tested against the data sources to determine their legitimacy, and were further refined. This approach to analysis resulted in grounded theory (Strauss & Corbin, 1994).



## FINDINGS

In this section, themes from the cross-case analysis of prospective teachers' learning about science inquiry are presented. Findings are organized around three major themes associated with prospective teacher learning that emerged during analysis of data. Data from multiple sources are used to illustrate points associated with each theme.

### **Theme #1: Engaging in learning about science inquiry influenced prospective elementary teachers' thinking about science and doing science.**

During the initial interview the prospective teachers were explicitly asked about their understanding of science and what it means to do science. They were prompted to give examples of someone doing science and to represent their understanding with real life examples whenever possible. On some occasions they were asked to describe themselves doing science. Eight of the 11 prospective teachers struggled to articulate their thinking about what science is and how someone does science. When asked to define science, many provided general responses that tended to equate science and the natural world or topics of scientific study. For instance, Sam stated that,

Science would deal with nature, I would think. Science deals with a lot of different things, like life processes and how we live, the outdoors, like nature, insects, how they relate to us...I think that is science...It's a very vast subject. Science is there – it is natural (pre-course interview).

Similarly, Tina explained, "I would say science is everything around you. What makes something work, how we live, just everything around us is science" (pre-course interview).

These types of responses were characteristic of the group and suggest that prospective teachers viewed science as something that exists around us, yet is independent from us as knowers. There is also the underlying sense that science is a merely a collection of explanations used to describe how the world works.

The pre-interview progressed from asking prospective teachers about their images of science to their ideas about what it means to do science. Again, participants struggled to explain their thinking and provided vague responses associated with learning new information. For example, Sara described doing science as "...a way of figuring out how things work, how organisms work. Basically, you ask questions and you try to find out the answers" (pre-course interview). Morgan described a similar view when she stated, "Like you do science, just like

exploring. If you are trying to find answers to questions and doing different experiments, or researching something or studying something, then you are kind of looking for answers” (pre-course interview). Like Sara and Morgan, most prospective teachers explained what it means to do science in terms of discovering answers about how the world works. This is very consistent with their representations of science in general. While they acknowledge science as a way of learning new information, the new knowledge is that of discovery rather than generation. Inherent in this view is that science is a collection of truths about the world that we seek to uncover. Doing science appears to be the way in which we learn these truths about our world.

Apparent in prospective teachers’ responses about doing science was a sense of process. However, there is little evidence to suggest that they understood the nature of the process itself. This was evident when prospective teachers were pressed to further explain what is involved in the process of doing science. They typically made vague references to research and experiments. It is important to note, however, that the prospective teachers’ use of the term *research* often referred to looking up known answers to questions in reference books or other resources. In her explanation of doing science, Katy stated, “You could be doing anything. Like experiments or just reading” (pre-course interview). Like Katy, Mrya also included vague terminology when she stated “You can be observing and hypothesizing and everything” (pre-course interview). While these prospective teachers mentioned an experimental aspect of doing science, their responses are limited to a series of science-related words. There is no indication that they understood how experimentation leads to explanations and understandings of concepts.

Many of the prospective teachers mentioned the scientific method and recalled learning about it in science class. Interestingly, many expressed that although there is a scientific method, it is not necessary to follow the steps when doing science. Jana stated,

In high school they are always giving us the rules about having your hypothesis, testing your hypothesis, and there was an order to it. I think you have to have the variables and you have to set things, but I don’t think there is a way you have to go about it – really (pre-course interview).

Similarly, Morgan explained that you are doing science...

... if you are trying to find answers to questions and doing different experiments or researching something or studying something. I guess there is the scientific method or whatever...but I don’t think you need it to be doing science (pre-course interview).

As suggested here, the prospective teachers in this study placed a great deal of importance on science as a means of finding answers, and demonstrated limited understanding regarding the processes of doing science, particularly the experimental aspects of science as inquiry.

A peripheral but related aspect of prospective teachers' initial thinking about science and doing science was their inability to distinguish between school science (i.e., learning about science) and what scientists do. In some extreme instances, science was directly equated with science class. For example, when asked to describe what it means to do science, Morgan responded, "The first thing that pops into my head I guess is science class. Because it is called science, you are obviously doing science" (pre-course interview). This inability to separate science and school science appears to be related to prospective teachers' views that everyone can do science. Sam explains,

I think science is purposeful and done with intent – I mean as far as professionals it is done with intent. I think the majority of the population, there is more of a majority that it is not really done with intent. Just little kids going out and collecting butterflies and just, you know, experiencing nature and things like that. Just exploring. That is scientific exploration (pre-course interview).

In contrast, several prospective teachers viewed scientists' science as separate and inaccessible to non-scientists. Ally explained, "If you are going to collect data and everything, I still kind of think only scientists can really understand and do that. I don't think that everyone can do it" (pre-course interview).

After having spent eight weeks engaged in an authentic science investigation, the prospective teachers' became more articulate about aspects of conducting scientific investigations. Moreover, there was a noticeable shift in emphasis from the products of science to the processes of science. Nevertheless, prospective teachers' understandings of scientific inquiry were still exposed as fragile. For example, Sara stated,

You come up with a question that you want to know and ... then you can go about setting up the experiment. Doing it that way and coming up with some data and some research. Put it together and trying it and then coming up with your answer. Then that would probably lead to another question. It is kind of a big ongoing process, I think, instead of a one stop kind of question and answer (post-course interview).

Later in the interview, she elaborated,

It was just this process that to go about things that I thought they had to be all these huge, you know, sets of problems that you always had to find out the correct answers. Now I

know that it can just like, even if you don't find out the actual answer you are looking for, you find out the range of things that can lead to new questions or new thought (post-course interview).

Jackie, another prospective teacher, explained,

Well, I originally thought that you asked a question and you do the experiment and you get your answer. What I think I learned is that you experiment and you get AN answer, MAYBE. And then there are all these other questions (post-course interview)!

While prospective teachers' notion of science inquiry became more experimental in nature, it is not clear that they understood the underlying purposes for doing experiments or the role of evidence in scientific explanations. Prospective teachers did express that experimentation has an important role in science, however they failed to represent the underlying relationships that exist between aspects of the experimental design. For example, even though many identified data as an important part of doing science, few articulated how the type of data collected influenced the analysis and interpretation, or the construction of explanations. Overall, there was little emphasis on the role of evidence in making scientific claims or explanations. Fortunately, by the end of the course prospective teachers were able to shift away from the idea of only one right answer for a scientific experiment or problem. As illustrated earlier, many noted that answers and explanations were often accompanied by new questions. This movement away from focusing on answers is reflected in prospective teachers' thinking about science learning and teaching (see Theme 3).

Another notable finding that may provide insight into prospective teachers' thinking about science and scientific inquiry was an issue that became evident about half-way through the course. During a class discussion, it became apparent that a number of prospective teachers viewed scientific inquiry as being very similar to modes of inquiry in other fields, such as history or mathematics. During this class period, prospective teachers were explicitly asked if inquiry in science was the same or different than inquiry in other areas. Their responses had to include a rationale for their answer. Although they were engaged in learning science as inquiry through their involvement in an investigation project, the prospective teachers were unable to articulate the aspects of that process that were unique to science. Central to their definition of inquiry in any field was asking questions and seeking answers through "testing, experimentation and research." In general, these terms were used in a colloquial sense. Most prospective teachers,

however, described inquiry in science as involving more hands-on, physical manipulation. For example, Jess characterized inquiry by saying,

[Inquiry in science and inquiry in other areas] have the same basic characteristics, such as questioning and thinking about answers and researching. In science [there is] more hands-on testing and the answers are not always going to be right for sure, as opposed to math and history (class discussion).

Similarly, Jackie described,

They have the same basic steps – ask questions, get actively involved in exploring material, come to conclusions, share those conclusions. There might be more of a focus on experimentation than other disciplines. [Science is] more manipulative than other disciplines. There is more than one right answer (class discussion)

Myra discussed inquiry in various fields as having the same basic components,

... starting with information and looking further. But in science I think it takes a lot more hands-on experimentation and finding answers a lot more on your own, whereas in history class you could probably search for an answer in a book (class discussion)

Jess, Jackie and Myra began to differentiate science inquiry as more hands-on, but were unable to articulate their meaning of hands-on beyond simple, physical experimentation. The prospective teachers' emphasis on hands-on activities as a fundamental aspect of science was also apparent in their thinking about science learning and teaching (see Theme 3).

**Theme #2: When prospective teachers struggled with particular aspects of their investigations, those aspects became foci of change in their thinking about science and doing science.**

A central finding of this study is the close connection between the ways in which the prospective teachers came to view science and doing science and the idiosyncratic struggles encountered during their investigations with insects. In general, prospective elementary teachers became more aware of and able to articulate aspects of scientific investigations and tended to emphasize the issues they struggled with the most during their projects. It seems that encountering and overcoming problems during the experience enabled the prospective teachers to develop a more appropriate understanding of the scientific process than their peers who did not struggle with aspects of the investigation. For example, one group encountered difficulty during their investigation with refining their initial question into smaller testable questions.

Jackie admitted that refining their question and controlling variables was the biggest obstacle in conducting their investigation. She explained,

We soon realized however that this question involved too many variables and could not be controlled for accuracy. In further discussion we identified four specific areas that could be isolated and tested one at a time to ultimately provide an outline for the ideal environment. As I mentioned above, our most significant obstacle was probably that our original question was so broad. We overcame this obstacle by breaking the question up into smaller sections (research presentation).

Subsequently, the role of developing testable questions and controlling variables emerged as a central feature of this group's explanations for doing science. Jana described her developing ideas about the scientific process,

Well, coming up with a question would be the first thing. Then if you have to, to break that down, questions that you can answer to solve the big question. Then experimenting and doing research about it to understand maybe the background of whatever you are trying to find out (post-course interview)

Clearly Jana's interpretation of doing science was reflective of what the group had experienced with their inquiry project.

In another group, the primary issue encountered was that of an unanticipated variable. This influenced data collection to the extent that the group was forced to redesign their project and collect data again. This feature of conducting investigations emerged as central in their descriptions of doing science. For example, Sara stated,

Sometimes when it doesn't go as planned you sometimes learn more. Because you have to think about, well, what can I do to fix – not necessarily fix – but go back and try to come up with a better way to do this. You learn more in the process because for crickets, we did not know that the dog food was going to actually gain weight – we only accounted for moisture loss. And so that happens when you actually learn more about humidity. You actually learn more sometimes when there are mistakes (post-course interview).

Finally, there was a group that struggled to make sense of a large amount of complex data collected over multiple experiments and trials. Given the overload of data near the end of their investigation, the group found it necessary to narrow the focus of their project, refine their methods, and collect data again in a more systematic way. Like their peers, this was reflected in their explanations for doing science. Tina, for instance, described science as doing "...research, questioning, refining questions. Comparing your data is the big thing. Like what you got in the



beginning and then going back and looking and really deciding what it is.” (post-course interview)

The connection between the struggles associated with prospective teachers’ scientific investigations and developing aspects of their explanations for doing science was further supported by the explanations for doing science provided by those who did not overcome a struggle associated with their inquiry projects. For example, one group in particular did experience problems during their investigation; however, they handled the problems differently than the other groups. Rather than attempt to overcome the difficulties that arose, this group backed away from the problems and moved in a different direction. Therefore, as a result of dropping the more difficult experiment, their investigation ran smoothly from start to finish. At no time were they challenged in their collection or interpretation of data, or in the development of explanations and conclusions. Although their explanations for doing science became more focused on experimentation, no aspect of the process emerged as salient for them. Abigail’s views of doing science illustrate this point. She stated,

I think it probably has to do with coming up with questions. Basically all the stuff with inquiry -- observing, collecting the data and making conclusions from all the data. And then you also have to take the variables into account. Just do lots of trials of the experiment. (post-course interview)

While Abigail describes the procedures that her group followed; she does not emphasize any aspect of the experience as being particularly important. In addition, although she articulates components of experimentation, the experimental nature of science inquiry did not emerge as a prominent feature of her interpretation of doing science. While it is not surprising that prospective teachers’ views of doing science reflect their personal experience with the process, it does have important implications for science teacher educators as they attempt to craft inquiry-rich experiences for prospective teachers.

**Theme #3: While prospective elementary teachers’ experiences engaging in science investigations influenced their thinking about science, it had limited influence on their conceptions of supporting children learning science as inquiry.**

The prospective teachers in this study entered the course with a strong interest in providing hands-on science experiences for children. They clearly valued children being able to interact with and manipulate materials related to the concepts they were learning. However, their



purposes for including such activities were related to creating involvement on the part of students and promoting interest in science as opposed to developing meaningful, conceptual understanding. For example, Abigail explained,

Hands-on engages them more. If you have them getting up and looking at insects they would be a lot more interested than if I stand up there and say 'Now the mealworm does this...' It is important for them to do what they are learning." (pre-course interview)

Similarly, Jana stated, "I think everybody learns best hands-on. Just hearing it doesn't help as much as seeing and doing it. Working with whatever you are talking about" (pre-course interview).

Although the prospective teachers advocated hands-on science, they viewed their role as teacher in terms of disseminating knowledge (i.e., providing answers). Consistent with the view of teaching science as providing answers were the prospective teachers' persistent concerns with content and their fear of being unable to respond to children's questions with the "correct answer" during instruction. Katy emphasized this point when discussing a reading passage on productive questioning.

It was nice to know that as a teacher it is all right to say, 'I don't know, but why don't we try to find out' if a student brings up something that you are not sure of. This was always one of my concerns because it puts you on the spot and you know how important it is for the student to receive the correct answer and not something you have to come up with (threaded discussion).

Jess further emphasized these concerns while reflecting back on her Hands-On Bugs experience. She remarked, "Honestly, I was a little nervous and leery about waking up on a Saturday morning to teach kids about bugs. I didn't think I would be able to answer the children's questions or keep their attention" (threaded discussion). On the topic of children's questions she related a recent experience, "Just the other day I was doing fieldwork in a classroom, as student asked me a question like the ones described in the book. I was flustered and upset with myself for not immediately knowing the answer" (threaded discussion).

Interestingly, one aspect of several of the prospective elementary teachers' thinking about science learning and teaching that changed over the course of the semester as they engaged in learning science as inquiry was their willingness to consider a question-driven approach to science teaching. After having engaged in a science investigation and exploring the role of questions in doing science, questions took on a more central role in school science for these

prospective teachers. Sara explained, “I think at the beginning, just observing, asking questions. I think it is really important before you can even think of doing a lesson with the kids.” (post-course interview) Similarly, Jess stated, “I feel more comfortable about handling children’s science-related questions and how I would go about aiding them in the inquiry process” (threaded discussion).

Related to this is the developing view of many prospective teachers that science inquiry can serve as a tool for investigating children’s science wonderings. Tina explained,

Teachers are supposed to know everything, but there are some students that will ask a question that a teacher might not know. This could lead to a great inquiry project. Instead of saying ‘I’m not sure of that answer, but I will find out for you’ the teacher could have the students find out their own question by researching, exploring and gathering data (threaded discussion).

Similarly, Ally stated,

I want them to be performing their own experiments, to be asking questions. If they were to come up with a question, I want to explore that question with them and have them be able to do an experiment and find data (post-course interview).

As mentioned previously, this noticeable emphasis on children’s ideas and questions stands in contrast to prospective teachers’ initial discomfort toward children’s questions. However, several appeared to recognize the inherent challenges in supporting children learning science as inquiry.

Morgan explained,

I think that running an inquiry classroom must be very difficult because the teacher always has to be on their toes. They have to be real good at asking the right questions to head students in the right directions without taking away their independence and control of the subject matter (threaded discussion).

Overall the prospective teachers in this study made several shifts in their understanding about science as inquiry that impacted their thinking about science teaching and learning. The most visible change that occurred was with regard to the increased emphasis on experimental science and a more appropriate understanding of the scientific process. Perhaps the most notable finding of this study is the importance of engaging in science inquiry and having to face and overcome problems that arise during the experience. This has sizeable implications for how we approach engaging students in science as inquiry within the classroom. Finally, while the experimental aspects of science inquiry were not clearly visible in their representations of teaching science,

prospective teachers did embrace a more question-driven approach. This stands as starting point to integrate science as inquiry into their developing pedagogy for teaching science.

## DISCUSSION

This case study of prospective elementary teacher learning within the context of an innovative life science course illustrates the struggles they encountered as they experienced learning science as inquiry for the first time. Many of these struggles are similar to those of prospective teachers described in the literature; however, the findings are hopeful in that they suggest that such carefully crafted learning experiences can indeed assist prospective teachers in developing more appropriate conceptions of science and school science. In the discussion that follows, patterns associated with prospective teacher learning about science as inquiry are examined in light of the literature in this area.

The prospective elementary teachers in this study entered the course equating science with the natural world and describing doing science as the process of figuring out how the world works. Inherent in their responses was the notion that science consists of a collection of answers or truths about the natural world that we seek to discover. These views are consistent with the literature on prospective teachers' conceptions of the nature of science (Abell & Smith, 1994; Bloom, 1989; Murcia & Schibeci, 1999). In a recent study by Murcia and Schibeci (1999), the conceptions of the nature of science of 73 prospective primary school teachers were examined. Results indicated that most did not hold views consistent with contemporary philosophies of science. In particular, most prospective teachers perceived science as "the process of discovery in which the truth about the world is uncovered" (p. 1136). The authors attribute this to the positivist assumptions that still pervade the school science experience.

Over the course of the study, the prospective teachers described here shifted to thinking about science in terms of processes as opposed to merely products. More specifically, they developed a strong emphasis on experimentation, particularly those aspects with which they struggled during their science investigations. Although these views are still considered to be inconsistent with modern philosophies of science, and experimentation is certainly not the only way science is done, these conceptions appeared to be useful in helping prospective teachers think about school science differently. For example, as prospective teachers became more attentive to the processes of science, their interest in childrens' questioning and strategies for

supporting childrens' science explorations in the classroom became a central feature of school science. Knowledge of how to design an experiment or activity that would provide useful information to such questions was something they did not have prior to this experience.

Ryder, Leach and Driver (1999) examined the views of the nature of science of 11 students involved in project work during their final year at the university. They reported that,

The nature of scientific lines of enquiry includes issues such as where scientific questions come from and how lines of work are continued or not. The way students characterized the nature of scientific lines of enquiry was a dominant feature of their conversations with us. It was also an aspect of students' thinking which appeared to be modified as a result of project work. (p. 211)

For example, those students who worked on experimental projects struggled to collect data that was reliable. In turn, many of these students' images of science included, "...the need to ensure that data is reproducible and that personal persistence and determination are important characteristics of the research scientist." (Ryder & Leach, 1999, p. 953).

The tendency for learners' images of science to be modified in terms of their personal experiences during scientific investigations can be explained by considering the situated nature of cognition (Brown, Collins, & Duguid, 1989; Bruner, 1990; Lave & Wenger, 1991). Putnam and Borko (2000) explain that situative theorists dispute the learning as knowledge acquisition perspective, and assert that...

...the physical and social contexts in which an activity takes place are an integral part of the activity, and that the activity is an integral part of the learning that takes place within it. How a person learns a particular set of knowledge and skills, and the situation in which a person learns, become a fundamental part of what is learned. (p.4)

While the prospective teachers in this study incorporated aspects of scientific investigations consistent with their experiences, particularly their struggles, other critical aspects of engaging in science as inquiry were conspicuously absent in their definitions of science and doing science. Case in point was the lack of attention to the role of evidence in constructing scientific explanations. While they became more articulate about how to engage in science investigations and emphasized the importance of experimentation in science, they seemed to focus on the processes that produce an outcome or answer. While this is positive in light of their inability to do so at the beginning of the semester, their representations still lacked complexity in terms of how explanations are developed and evaluated. Some have suggested that understanding the relationship between evidence and explanation/theory is fundamental to

developing appropriate understandings of the nature of science and scientific inquiry (Carey, Evans, Honda, Jay, & Unger, 1989; Gott & Duggan, 1996). This raises important questions about the kinds of learning opportunities we as teacher educators need to craft in order to help prospective teachers learn about science and scientific inquiry (see Implications).

Finally, the prospective teachers described here placed a great deal of emphasis on hands-on experiences as a requirement for learning in science. This tendency for prospective elementary teachers to embrace the notion of hands-on activity is prevalent in the literature. Moreover, it has been demonstrated that these conceptions of science teaching and learning can be developed into a more conceptual perspective when that is the target of change of courses in subject-specific pedagogy (Gustafson & Rowell, 1995; Zembal, 1996; Zembal-Saul, et al., 2000). Although that was not the central purpose of the science content course taken by the prospective teachers in this study, interesting changes in the area of science teaching and learning were noted.

It was reported in the findings that while the prospective teachers' images of science and doing science were influenced by their experiences learning science as inquiry, these changes were not reflected to the same extent in their thinking about science teaching and learning. However, there appeared to be a parallel shift in their thinking about science more in terms of questions than answers and their willingness to consider science inquiry as a tool for exploring children's wonderings. As long as science is viewed as a collection of truths or answers about the world, then it stands to reason that the role of the teacher is one of disseminator of knowledge. These are views that were initially espoused by the participants in this study. As the prospective teachers came to place greater emphasis on questions, observations, and experimentation as fundamental aspects of doing science, they became more open to approaches to teaching science that encourage children to investigate phenomena about which they have questions. In other words, the need to serve as disseminator of knowledge was minimized. These developing views of science teaching and learning, while still far from appropriate, are possibly developmental stepping stones on the path to realizing the vision of reform put forth in the standards (NRC, 1996). The parallel nature of the shift in prospective teachers' thinking about science and teaching science certainly warrants more research.

## CONCLUSIONS & IMPLICATIONS

The findings of this study of prospective elementary teachers' learning about science inquiry within the context of an innovative life science course suggest that specially developed science content courses such as the one described here can assist prospective teachers' in developing more appropriate conceptions of science and school science. While a number of persistent issues were reported, in general the prospective teachers did come to view science in terms of processes versus merely products. In addition, they developed a more in-depth understanding of the experimental aspects of some scientific endeavors. Some elements of science inquiry even emerged as part of prospective teachers' thinking about children's science. While it is important to examine the nature and development of prospective teachers' conceptions of science and scientific inquiry, this research also provides implications for science teacher educators as we reconceptualize programs and design courses to support the development of elementary teachers who are prepared to realize the vision of reform. Two fundamental implications for science teacher education are addressed below.

An obvious concern is that all but one of the prospective elementary teachers in this study reported that this was their first experience learning science as inquiry. While in and of itself, subject matter knowledge is insufficient for teaching for meaningful understanding, it is necessary (Borko & Putnam, 1996; Cochran & Jones, 1998; Grossman, 1990; Magnusson, et al., 1999; Mapolelo, 1999; Putnam & Borko, 1997; Shulman, 1986, 1987; Zembal-Saul, et al., 2000). In this case, the need to consider syntactical, as well as substantive, aspects of subject matter was revealed as essential. Thus, the first implication is the need for prospective elementary teachers to develop rich subject matter knowledge, including knowledge of the nature of science and norms of scientific work, as part of their university coursework – not to mention their K-12 science learning experiences. Teacher education is the responsibility of the entire university community, not solely that of colleges of education. As teacher educators, we must seek out opportunities to collaborate with our colleagues in the sciences to develop authentic science learning experiences as part of the general education coursework of elementary education majors (see Boardman, et al., 1999; Dana, et al., 2000; Zembal-Saul & Oliver, 1998). With multiple opportunities to experience learning science as inquiry, prospective teachers should be more prepared to translate those experiences into considerations for supporting children's science learning as part of their subject-specific coursework.



A second implication that stems from this work is the need to carefully consider the types of learning opportunities we craft for prospective elementary teachers. As mentioned previously, the participants in this study experienced changes in their thinking about science and doing science that were consistent with the kinds of struggles that they encountered during their science investigations. This suggests that we may want to target particular aspects of science inquiry that we consider to be fundamental, and problematize them for prospective teachers learning science as inquiry. All scientific investigations are not created equally. Struggling with various aspects of scientific processes is a potentially powerful part of meaningful science learning.

In closing, we raise an issue that we have continuously struggled with in our work with prospective elementary teachers. That is, what are the requisite understandings about the nature of science and scientific work that prospective elementary teachers must have in order to be able to realize the vision of reform (NRC, 1996)? Abd-El-Khalick, Bell and Lederman (1998) suggest that there is "...an acceptable level of generality regarding the nature of science that is accessible to K-12 students and also relevant to their daily lives." (p. 418). While these types of discussions have become increasingly common as they pertain to secondary science and science teachers, there is little agreement at the elementary level. Can we realistically expect elementary school teachers, who are prepared as generalists, to develop the same kinds of conceptions of science that we expect at the secondary level? If not, what knowledge, skills, and dispositions are necessary to support children's meaningful and authentic science learning? Clearly these questions warrant closer consideration. For when we better understand what elementary teachers need to know about science and doing science to support children in learning science as inquiry, then we will be better equipped to craft learning opportunities that promote the development of these understandings.

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