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Preservice Elementary Teachers' Perceptions of Their Understanding of Inquiry and Inquiry-Based Science Pedagogy: Influence of an Elementary Science Education Methods Course and a Science Field Experience

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The *National Science Education Standards* (*NSES*) advocate teaching and learning science through inquiry (i.e., through exploring and discovery) (National Research Council [NRC], 1996, 2000). *Inquiry* in the *NSES* is defined as "a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results" (NRC, 1996, p. 23). Embedded in this definition are the five essential features of classroom inquiry articulated by the *NSES* document (NRC, 2000):

1. Learners are **engaged** by scientifically oriented questions.
2. Learners give priority to **evidence**.
3. Learners formulate **explanations** from evidence.
4. Learners **evaluate** their explanations in light of alternative explanations.
5. Learners **communicate** and **justify** their proposed explanations. (p. 25)

The *NSES* document states that "Inquiry into authentic questions generated from student experiences is the central strategy for teaching science" (p. 2). This approach is consistent with the constructivists' view that learning is a process of building up of structures of experience where prior knowledge and experiences add to new understandings (Shank, 1993).

According to the *NSES*, classroom inquiries can be *partial* or *full*. *Full inquiries* are those where all five essential features of classroom inquiry are present, whereas *partial inquiries* are those investigations in which one or more essential features for classroom inquiry are missing such as when the "teacher chooses to demonstrate how something works rather than have students explore it and develop their own questions or explanations" (NRC, 2000, p. 28). Additionally, according to the *NSES*, inquiry-based teaching can vary in the "amount of structure, guidance, and coaching the teacher provides for students engaged in inquiry" (p. 28). The degree to which teachers structure what students do is sometimes referred to as *guided* versus *open* inquiry. The more responsibility learners have for posing and responding to the questions, designing investigations, and extracting and communicating their learning, the more *open* the inquiry, while the more responsibility the teacher takes, the more *structured* or *guided* the inquiry (NRC, 2000).

For students to grasp inquiry concepts, the *NSES* recommend that teachers use inquiry-based science pedagogies and provide multi-investigational opportunities for students to do science (Barrow, 2006). However, scientific inquiry has not been a prominent feature of science teacher preparation (Zembal-Saul, Blumenfeld, & Krajcik, 2000), and both elementary and preservice teachers have not been exposed to inquiry-based pedagogy recommended by the *NSES* (Haefner & Zembal-Saul, 2004). Consequently, both inservice and preservice elementary teachers lack self-efficacy to teach science (Appleton, 2006). Taken together, these findings indicate that prospective elementary teachers graduating from teacher preparation programs are not prepared and are not confident about their understanding of inquiry or inquiry-based pedagogies for teaching science.

A study examining experiences of elementary preservice teachers (ePSTs) in a content-specific field-based experience with elementary science specialists (Varma & Hanuscin, 2008) has shown that ePSTs readily embrace the reform-based pedagogy of the specialists who mentored them in the field experiences. Research suggests that methods courses have the potential to shape the practice of new teachers (Abell & Bryan, 1997; Gess-Newsome, 1999). Consequently, if inquiry-based pedagogy is integrated into the elementary science education methods course (eSEM) and the science field experience, these can provide important avenues for exposing ePSTs to inquiry-based pedagogy and improving their self-efficacy to teach science (Bleicher, 2006; Morrell & Carroll, 2003; Palmer, 2006; Rice & Roychoudhury, 2003; Wheatley, 2000, 2001).

Research Gap

Most research on the teaching of science, to date, has focused on the elementary preservice teachers' (ePSTs') confidence to teach after completing a methods course, field experience, or specialized inquiry-based science content courses (Bebout, Jones, Raftery, White, Bobango, & Fowler, 1992; Downing & Filer, 1999; Duran, McArthur, & Hook, 2004; Friedrichsen, 2001; Hancock & Gallard, 2004; Jarret, 1999; Jones, Buckler, Cooper, & Straushein, 1997; Lee, Hart, Cuevas & Enders, 2004; McLoughlin & Dana, 1999). Although research has not directly addressed inquiry in science education, one study evaluated how prospective early childhood education (ECE) teachers' ideas about science education change as a result of implementing inquiry-based curriculum within the ECE science methods course (Plevyak, 2007). In another study, researchers identified the dilemmas faced by science education instructors for teaching inquiry in context of the elementary science methods (eSEM) course (Newman, Abell, Hubbard, McDonald, Otaala, & Martini, 2004) and attributed these dilemmas to varying definitions of inquiry in science education literature.

Literature indicates that the *NSES* teaching standards and inquiry-based teaching strategies for science are not uniformly incorporated into the eSEM courses across the country (Barrow, 2006; Smith & Gess-Newsome, 2004) and that field experiences might not provide appropriate models of the inquiry-based science pedagogy recommended by the *NSES* (Abell, 2006). Therefore, as ePSTs begin to form their beliefs about learning and teaching science through the eSEM course and science field experience, capturing their perceptions of their understanding about inquiry and inquiry-based science pedagogy can provide valuable information for the evaluation of the eSEM course and associated field experience in meeting the recommendations of the *NSES* for teaching science as inquiry. However, no research to date has specifically examined the ePSTs' perceptions regarding their understanding of inquiry and inquiry-based pedagogy to teach science after concurrently completing the traditional eSEM course and the science field experience, two avenues available for prospective elementary teachers to learn, observe, or formulate pedagogical strategies in science consistent with the *NSES* recommendations for inquiry-based instruction and learning in science (NRC, 1996, 2000).

The purpose of this research was to discern whether and how the recommendations of the *NSES* to teach science through inquiry are integrated into the eSEM course, and to determine from ePSTs' perspectives their understanding about inquiry and inquiry-based pedagogy for teaching and learning science after concurrently completing an eSEM course and its associated science field experience.

According to the qualitative researchers' viewpoint, "reality comes to be understood to human beings only in the form in which it is perceived" (Bogdan & Biklen, 2003, p. 24). Also, Enochs and Riggs (1990) point out that "beliefs may account for individual differences in teacher effectiveness" (p. 694). Additionally, according to the theory of social learning (Bandura, 1997) as explained by Enochs and Riggs (1990), "people develop generalized expectancy concerning action-outcome contingencies based on life experiences. They develop specific beliefs concerning their own ability to cope" (p. 695). Therefore, capturing the preservice teachers' perceptions (beliefs) about their understanding about inquiry, inquiry-based teaching, and learning is essential and consistent with the theoretical perspective of this study and with what is being reported in literature regarding the capturing of individuals' understanding of reality.

Therefore, the theoretical perspective most relevant to this research is phenomenology, which attempts to understand the meaning of events and interactions from the point of view of participants (Bogdan & Biklen, 2003; Douglas, 1976). Phenomenological inquiry attempts to understand the conceptual world of the subjects and is the search for understandings and meanings that the involved participants, themselves, hold about an object, person, or situation (McLoughlin & Dana, 1999).

Primary data evaluated in this study were the ePSTs' reflections captured within the focus group discussions. The goal was to examine ePSTs' perceptions regarding their understanding of inquiry and inquiry-based pedagogy in three dimensions: (1) the abilities that students should possess to do scientific inquiry, (2) the understanding students should have about scientific inquiry, and (3) how teachers should teach science through inquiry. Reflections are an important component of phenomenological research as they help to recapitulate the participants' experiences to create a reflective cognitive stance through which meaning can be assigned to events and interactions experienced by people (Van Manen, 1990). Other researchers (Abell, 2006; Abell & Bryan, 1997; Bogdan & Biklen, 2003; Doecke, Brown, & Loughran, 2000; Pryor & Kuhn, 2004) point out that course discussion and reflection are critical to ePSTs' ability to integrate theoretical understandings in making sense of school observations. The findings from this research support the improvement of pedagogical experiences for ePSTs offered through the eSEM course and the associated science field experience.

Research Question

Given the critical role that preservice teachers' (ePSTs) own beliefs and perspectives play in shaping their learning, we sought to better understand from their perspective the influence of the methods courses and field experiences on their understanding of inquiry and inquiry-based teaching and learning.. Therefore, the research question that guided this research was as follows:

> What do elementary preservice teachers' perceptions indicate regarding their understanding of inquiry and inquiry-based pedagogy for teaching and learning science as recommended by the *NSES* after concurrently completing the elementary science education methods course and its associated science field experience?

Methodology

This research was designed as a qualitative study. Qualitative research has the capacity to enable inquirers to identify the understandings held by individuals and the meanings they make of their experiences (Erickson, 1998). According to Bogdan and Biklen (2003), qualitative research does not "transcend truth but instead renders or interprets reality grounded in the empirical world" (p. 24) and "qualitative researchers tend to be phenomenological in orientation" (p. 24). The design of this research study is consistent with the key characteristic defined for a naturalistic inquiry (Lincoln & Guba, 1985, pp. 39-45) in that this research used human instruments for primary data gathering, was conducted in the natural setting of the students (classroom), and used mostly qualitative methods such as interviews and focus groups to capture data as these methods help to deal with multiple realities which are inherent in the perceptions of individuals and can be varied based on the meaning each individual draws from his or her experience even when it is the same for all participants.

Participants

Participants included 40 ePSTs from a four-year undergraduate teacher education program who were enrolled in an elementary science education methods (eSEM) course and concurrently participating in an elementary science field experience at a large Midwestern university. All were White females and of either junior or senior standing. Other participants included a graduate teaching assistant and the professor (hereby referred to as instructors throughout this manuscript) who taught the two sections of the eSEM course.

Elementary Science Education Methods (eSEM) Course

This study was conducted on a large Midwestern university campus. The elementary education courses in this university's teacher education program are taught in *cohorts* of approximately 20 to 30 students. Students are enrolled in a 12-credit-hour *block* which includes science, math, and literacy methods courses as well as a field experience. The eSEM course is a laboratory and research-based course designed to integrate theory and practice. Two sections are offered each semester. At the time of this study, one section was taught by a faculty member, and the other by a graduate teaching assistant. Identical syllabi and activities are planned for each section. The goal of the eSEM course is to help preservice teachers integrate their understanding of the instructional strategies they learn, with their observations of these strategies being implemented in the elementary classrooms. Accordingly, an important component of this course is the concurrent field experience. Through field placements in the elementary science classrooms, ePSTs are able to examine the problems of practice and are expected to begin the process of becoming inquiring, reflective professionals. Students in the cohorts are placed with mentor teachers (science specialists for grades 4-5 or classroom teachers for grades K-3) at local elementary schools within a large public school district. Each placement is for two hours per week for at least 12 weeks providing 24 hours of field experience in which the ePSTs observe delivery of instruction by mentor teachers and, on occasion, participate in different classroom activities. Limited hands-on teaching occurs in the form of helping students with their work or assisting the mentor teacher with the delivery of the lesson. In most cases, there is no independent teaching conducted by the students.

Data Sources

The following four data collection sources were used to capture ePSTs' understanding of inquiry and inquiry-based pedagogy:

1. *Focus Group Sessions (Appendix I).* Focus groups were used to capture ePSTs' reflective discussions on the teaching strategies modeled in the eSEM course versus those observed in the field, ePSTs' understanding of inquiry for teaching, and learning science through inquiry. A series of five focus-group interviews were conducted with ePSTs from both sections of the eSEM course. The reflective discussions of the preservice teachers were audiotaped and transcribed. Responses were coded by group number and respondent number (e.g., G1-S4 represents group 1, student 4). Transcripts from the focus groups served as the primary data source. Focus groups were convened toward the end of the winter semester 2006 to capture ePSTS' perceptions about their understanding of inquiry and inquiry-based pedagogy for teaching science after concurrently completing the eSEM course and its associated field experience. Responses from the focus groups are hereby referred to as the *received curriculum*.

2. *Interviews (Appendix II).* Structured interviews were conducted with the instructors teaching each section of the eSEM course in the winter 2006 semester to capture the teaching strategies (hereby referred to as the *delivered curriculum*) used to integrate *NSES* to teach science through inquiry. Interview questions were divergent (open) in nature to allow the gathering of specific information and reflection from the participants. Responses on the interviews were used to verify the categories and the assertions emerging from focus group data. The interviews were conducted toward the end of the 2006 winter semester. Anonymity of the instructors was maintained by coding their responses as P1 and P2.

3. *Evaluation of eSEM Course Syllabus and Materials.* Course documents (e.g., syllabus, handouts, etc., hereby referred to as the *intended curriculum*) were examined to assess whether and how recommendations of the *NSES* for teaching science through inquiry were incorporated into the course syllabus/materials and to validate findings from the focus groups and interviews.

4. *Study Specific Questionnaire (SSQ)* (*Appendix III*). Questions on the SSQ were designed to confirm findings from the primary data collection sources (i.e., focus groups, interviews, and course content evaluation). In this respect, the SSQ was a redundant data source specifically designed for this study to supplement the

findings from the primary and secondary data collection sources. A similar approach of using a study-specific questionnaire to supplement information being gathered through primary data collection sources has been used by other researchers (e.g., by Enochs and Riggs, 1990, during the development of the STEBI-B instrument). The SSQ consisted of 20 items in a five-choice, Likert-type scale format. Response categories included SA = Strongly Agree, A = Agree, UN = Uncertain, D = Disagree, and SD = Strongly Disagree. Of the 20 items in the questionnaire, 14 were designed to capture the ePSTs' understanding and knowledge about scientific inquiry, three questions were designed to capture EPSTs' confidence to teach science, and the remaining three questions captured their perceptions regarding similarities between the science teaching strategies modeled and taught in the elementary science education methods course and those observed in the field.

Data Analysis

Transcripts from focus groups served as the primary data. Data analysis started with assigning provisional categories to responses from the focus groups based on similarity and content of responses using the constant comparative method (Glaser & Strauss, 1967; Hatch, 2002; Lincoln & Guba, 1985). This approach has been used previously in research for evaluating preservice teachers' understanding of science teaching and learning (Haefner & Zembal-Saul, 2004) and for capturing undergraduate students' perceptions of an inquiry-based physics course (Duran et al., 2004). To get repeated confirmations of the emerging assertions for relevance, and to assure that emerging assertions were grounded in data (Hatch, 2002; Lincoln & Guba, 1985) and trustworthy, a comparison was done between data from multiple sources (e.g., focus group transcripts, interview transcripts, course material evaluation, and SSQ). Thus, consistent with the principles of grounded theory (Glaser & Strauss, 1999), data were used to generate assertions and not vice versa.

Findings

Review of eSEM Course Materials for Integration of the *NSES* Recommendation for Inquiry

Examination of the course syllabus, the course materials, and handouts showed that the instructors used the following teaching strategies to involve preservice teachers in multiple inquiry-based activities to teach them the abilities necessary to conduct inquiries and to give them understanding about scientific inquiry and how scientists work: (1) designing multiple inquiry-based experiences; (2) guiding and focusing student inquiries instead of lecturing; (3) the use of the 5E Learning Cycle Instructional Model (Bybee, 1997, 2000) encompassing the five essential features of classroom inquiry outlined by the *NSES*; (4) use of operational, scientifically oriented questions to initiate student investigations; (5) classroom discussions on inquiry-based science teaching and learning; (6) development of lesson plans and curriculum integrating *NSES* recommendations for teaching science as inquiry; (7) use of science notebooks for data collection and reflection; (8) evaluation of instructional material for suitability to teach science as inquiry; and (9) assessment strategies to evaluate student learning. All these strategies were designed to integrate the recommendations of the *NSES* for teaching and learning science as inquiry. The instructors had designed numerous projects to actively involve students in inquiries which spanned from structured or guided inquiries, wherein students were guided through the activity, learning skills, and vocabulary associated with inquiry, to more open, full inquiries, wherein students independently thought through the operational question posed, designed, and assembled equipment to investigate and answer the operational question (Table 1). This teaching strategy is consistent with the *NSES* recommendation for developing student abilities for conducting inquiry and understanding of inquiry through exposure to different types of inquiries during their learning of science (NRC, 1996, 2000).

Table 1. Course Activities and Type of Inquiry

	Types of Inquiries			
Activity	**Structured/Partial**	**Guided/Partial**	**Guided/Full**	**Open/Full**
Pendulum				
Stage I	X			
Stage II		X		
Magnetism				
Stage I	X			
Stage II		X		
Electricity				
Stage I		X		
Stage II			X	
Seeds				
Stage I	X			
Stage II		X		
Stage III			X	
Culminating Activity				X

The formative and summative assessment strategies taught in the course were designed to teach ePSTs how to evaluate students' knowledge of the abilities necessary to conduct inquiry and their understanding of concepts about scientific inquiry which is consistent with the *NSES* recommendation that in the context of inquiry, assessments need to gauge "the progress of students in achieving the three major learning outcomes of inquiry-based science teaching: conceptual understandings in science, abilities to perform scientific inquiry, and understanding of inquiry" (NRC, 2000, p. 75). The 5E Learning Cycle Instructional Model (Bybee, 1997, 2000) used by the eSEM course instructors to teach science through inquiry encompasses all the five essential features of classroom inquiry outlined by the *NSES* (NRC, 2000). Similarly, the instructors' use of operational, scientifically oriented questions to trigger preservice teachers' investigations and the guiding and facilitation done by the instructors to focus ePSTs' inquiries are all consistent with the recommendations of the *NSES* that teachers of science facilitate student learning by focusing and supporting inquiries (NRC, 2000). This is supported by interview transcripts with the instructors as represented in the response below:

> From a content perspective as well as from a teaching perspective, I focused on inquiry. They had some at the start of the semester. We did a learning cycle and that stressed prior knowledge and ways of accessing that. We

> had learning stations, learning packets, questioning strategies, operational questions, 4-question strategy. Demonstrated teaching strategies as a facilitator, and that is a new role that they have not encountered before. (P2)

Responses such as this indicate the integration of the recommendations of *NSES* into the course syllabus for the eSEM. Reflections of ePSTs from the focus groups also confirmed the integration of *NSES* into teaching strategies as exemplified by the responses such as "All the skills we used for inquiry are right out of the standards. For example we made observations, generated and recorded our data, kept lab notebooks, and then drew conclusions" (G5-S4) and "We saw how the *National Science Education Standards* are integrated into teaching of science" (G5-S6).

An interesting finding of this study was that the instructors indicated that during open inquiries, when there was little or no guidance given by the instructors, most of the ePSTs struggled with the constructivist approach to learning science as indicated by the following response by the graduate student instructor: "We really used open inquiry in the seed project, and they struggled (laughs), and they struggled pretty good" (P1). The instructors emphasized that even though working with open inquiries was frustrating to the ePSTs, they refrained from lecturing as they wanted them to understand and learn inquiry by experiencing it: "Predominantly they had to experience it. So rather than telling them, they experience it first hand, and then discussion afterwards which is frustrating for them" (P2).

This teaching approach through which the instructors allowed preservice teachers to learn through open inquiries is consistent with the *NSES* recommendations for inquiry and with Piaget's (1975) or the constructivist view on human learning (NRC, 2000). According to Piaget (1975), "learning begins when individuals experience disequilibrium" and to bring their understanding back into equilibrium, "they must adapt or change their cognitive structure through interaction with the environment" (NRC, 2000, p. 34). In keeping with this viewpoint, the NRC (2000) commentary on the *NSES* points out that experiences that vary in openness are needed to develop the abilities of students that are necessary to do inquiry and that "guided inquiry can best focus learning on the development of particular science concepts" while a "more open inquiry will afford the best opportunities for cognitive development and scientific reasoning" (p. 30).

Interestingly, the instructors pointed out that though the students were initially frustrated, their written journals and reflections indicated that inquiry-based teaching and learning was effective in teaching them the concept of what constitutes inquiry. This is implied in the response below from a graduate student instructor:

> Uh, but you see in their journals and their reflections that some of them are really there, I mean those that were interested in science were there, you know and it was very impressive, and you can kind of tell those maybe not so much but through the other more you know uh smaller classroom investigations you know they got to be uh better at investigating. (P1)

Rather than teaching to the text, the instructors integrated *NSES* recommendations for teaching science using inquiry-based pedagogy by designing inquiry-based activities and by facilitating and focusing student inquiries. Instructors facilitated inquiries by involving students in inquiry-based projects and by requiring the use of science notebooks for recording data and observations as indicated by the response below from the professor:

> I'm going to refer to the teaching standards of the National Science Education that you organize using inquiry as the driver. It's organizing it in multiple approaches from the perspective [of] active learning and one of the ways I facilitated that was through the use of science notebooks and then using projects, uh, the way of encouraging students to develop understanding through higher order thinking skills, and modeling constructivism. (P2)

This teaching approach is consistent with the *NSES* recommendations that teachers of science guide and facilitate learning (NRC, 1996). Thus, the intended, the delivered, and the received curriculum indicated alignment with the *NSES* recommendations for doing science as inquiry. The assertion that emerged from the data was that multiple inquiry-based science teaching and learning strategies were used to integrate the *NSES* recommendations for doing science through inquiry in the science methods course.

Elementary PSTs' Understanding of Inquiry

The understanding of scientific inquiry was examined through the following two dimensions outlined in the *NSES* (NRC, 2000) for learning science for grades K through 4: (1) fundamental abilities necessary to conduct a scientific inquiry and (2) fundamental understanding about scientific inquiry.

Fundamental Abilities Necessary to Conduct Inquiry

The majority of the ePSTs reported receiving no exposure to inquiry-based science teaching strategies prior to the eSEM course: "I had not done inquiry till this class" (G3-S2). Some indicated that even though they had been exposed to inquiry-based instruction in their science class, they did not recognize the instructional strategies as being inquiry-based and drew connections to inquiry only after inquiry and inquiry-based instructional strategies were emphasized in the science methods (eSEM) course as illustrated by the following response: "Like we had done some inquiry, but we didn't really know what it was called. And like we've heard the term thrown around before but never really applied it to teaching or how we could possibly teach that way" (G2-S5).

There was concurrence among ePSTs that the eSEM course had helped them understand what is meant by inquiry as exemplified by the following response: "I did not know anything about inquiry. Now I know that inquiry means to dig deep and find out what is going on" (G1-S6). Focus group transcripts also confirmed the use of multiple inquiry-based activities and teaching strategies by the instructors to develop ePSTs' abilities to conduct inquiries; the use of operational, scientifically oriented questions to trigger student questions and further investigations; and how to evaluate science instructional material and science curriculums for suitability to teach inquiry-based science lessons as indicated in the following response: "Also preparing inquiry-based lesson plans forced us to think more about . . . inquiry. This class made me comfortable with teaching science" (G3-S2). One activity that stood out from the ePSTs' reflections in the focus groups was the set of experiments they did to study the germination of seeds. Review of course materials indicated that the seed experiments were triggered by ten operational questions of which each ePST was required to answer at least four through design of inquiry investigations. These sets of experiments represented open, full inquiries as defined by the *NSES* (NRC, 2000) and were designed to teach ePSTs how to conduct inquiries and what constitutes an inquiry. Most dialog among ePSTs in the focus groups occurred on this project as indicated by the response below:

> We grew seeds and collected growth data for five weeks. We had to anticipate or predict and question what would happen over time. We kept a journal with the data in it. At the end of the five weeks, we compared our prediction with what we had observed and noted down. We were then required to raise some extension questions and explain what could be done to further examine the growth of seeds. Integration was done through exchange of ideas. (G1-S3)

This inquiry-based activity was important in that it took ePSTs through all the five essential features for classroom inquiry outlined by the *NSES* (NRC, 2000) with very little guidance from the instructors.

Fundamental Understanding About Inquiry

Focus group transcripts also indicated that ePSTs' vocabulary was consistent with the understanding of fundamental abilities for science as inquiry outlined in the *NSES* content standard for K-4 (NRC, 2000). For example, focus group transcripts indicated ePSTs' understanding that inquiry investigations start with probing questions that spark curiosity, require tools to find information, can raise more questions that could lead to further investigations, that there is not one specific answer for each phenomenon, involve reflecting back on what the data is indicating in light of what is already known, require doing more investigations to develop complete understanding, and could lead to the development of new knowledge or discovery as articulated in the following responses: "Okay, it starts with a prompting question or just something you want to know about, and then the facilitator provided tools and ideas and resources that you might need. I just wrote my reflection on this" (G5-S1); "Sometimes data can lead to further investigation—I mean it raises more questions which too have to be answered" (G4-S3); and "I think it represents exploring something that does not fit with what we already know" (G1-S3).

Not only did the ePSTs understand the fundamental concepts of what constitutes scientific inquiry, they also drew connections to the use of inquiry in other fields. Most notable was their analogy to the "Show Me" motto for the State of Missouri which, in a way, exemplifies what an inquiry investigation is: "Not accepting what we see but questioning everything. Just like the motto of Missouri, the "Show me" state, we must back up an explanation with information or data" (G1-S5). Another interesting finding was that ePSTs understood the connections between constructivist approach to learning and inquiry-based pedagogy, indicating their own cognitive development in the area of science pedagogy:

> I think a lot of the inquiry and constructivism issues overlap and so most of what I knew about it came from constructivism because that was heavily taught in our . . . previous classes. What I know of inquiry came from this class because we have like focused on it this whole semester. (G3-S6)

These findings are supported by the SSQ data which showed that the majority of the ePSTs (93.3%) responded positively on this questionnaire indicating their understanding of inquiry.

Thus, the data indicates that the eSEM course was successful in teaching ePSTs the abilities necessary to do inquiry and the understanding of the concepts related to scientific inquiry. The application of science concepts by preservice teachers to the workings of household appliances: "The little deals in the cabinets that keep them closed. Yeah, we really applied a lot of the stuff to our homes and how our everyday life, like how we applied science to our everyday life" (G2-S4); to inquiry principles for crime scene investigation as suggested in the following response: "Yes, what I mean is that it is an approach—that is, how we should go about investigating things just like on a crime scene" (G1-S1); and conflict resolution: "Well, in a way we use inquiry principles to investigate conflicts. We ask the when, how, who, and why of what happened" (G1-S2) are further indications of their understanding of inquiry and science. Making connections to the use of inquiry principles to explain day-to-day phenomena is consistent with the vision of the *NSES* for scientific literacy for all citizens (NRC, 1996). These findings indicate that ePSTs understood concepts associated with inquiry-based teaching and learning.

Understanding of Inquiry-Based Science Pedagogy

Preservice teachers' perceptions regarding their understanding of inquiry-based pedagogy for teaching and learning science was evaluated using the following two dimensions: (1) understanding the value of inquiry-based instruction in teaching and learning science and (2) understanding of the recommendations of *NSES* for teaching science through inquiry. Preservice teachers indicated an understanding of the value of inquiry for bringing about lasting/sustained student learning in science as indicated by the following responses: "If children are allowed to learn by doing, they will remember what they learned" (G3-S1) and "It teaches students how to overcome initial frustration and keep trying" (G1-S5). One notable point made by the ePSTs was that inquiry-based pedagogy can get students interested in science which could ultimately lead students to pursue science in higher education which would fill the shortage of scientists in the United States as indicated by the following response: "Children are naturally curious. If we let them explore, then they will like science and hopefully go into sciences when they grow up" (G3-S1).

It was very interesting to note that during their reflections in the focus groups, most of the ePSTs felt that using inquiry-based pedagogies would help them inculcate confidence in their students: "Students develop confidence when they are allowed to explore on their own" (G3-S3); would help them with classroom management: "The time passes faster when children are involved in activities than when say the teacher teaches to them" (G5-S5); and would help in bringing about learning through social interaction among students: "It promotes social interaction and learning from each other" (G1-S2). The finding that the ePSTs understood that inquiry-based science instruction can give students confidence in science is especially interesting since a recurring theme in science education research has been that ePSTs do not feel confident to teach science. The understanding of the value of social interaction for learning is a hallmark of the constructivist approach for learning science and is consistent with Bandura's (1977) contention that vicarious experiences wherein one learns through peer interaction promote self-efficacy.

Preservice teachers' responses also confirmed their familiarity with the recommendations of the *NSES* for teaching and learning science through inquiry. Focus group transcripts indicate that ePSTs achieved this primarily through involvement in class discussions on the *NSES*, observation of teaching strategies that used *NSES* recommendations for science as inquiry, and preparation and presentation of science lesson plans incorporating the recommendations of *NSES* as articulated in the following responses: "And we had to talk about the standards a lot and that really helped because the standards really do outline everything we need" (G5-S4) and "We saw how the *National Science Education Standards* are integrated into teaching of science" (G5-S6).

Review of the course materials indicates that class discussions and assignments were made on the use of operational questions for initiating thinking from preservice teachers. The instructors also emphasized to the ePSTs the importance of facilitating questions from students and allowing students to answer their own questions through investigations as indicated by the interview transcripts in the response below:

> Um, one of the things that we focus on or that we focused on in class was questioning, and I pointed out to them that, uh, you hear a lot of teachers' questions, teachers question all the time, but you don't listen to students' questions and from those come your investigations, your collection of data, and your gathering of evidence to explain and communicat[e] those ideas, so I think their picking up on that. Uh, whether they see it as a way science is done . . . you know as we went through the national standards hopefully they picked some of that up [mumbled], uh, and it's, uh, inquiry as a teaching strategy their [sic] coming to an awareness of that. (P1)

The use of operational questions to trigger student investigations is consistent with the *NSES* Teaching Standard B recommendation that "teachers of science orchestrate discourse among students about inquiry ideas and encourage curiosity" and that "instructional activities of inquiry should engage students in identifying and shaping an understanding of the question under inquiry" (NRC, 1996, p. 144).

An important part of teaching science through inquiry is to select instructional materials that might be beneficial in teaching science through inquiry. Also, one of the expectations articulated in the *NSES* is that teachers of science be able to analyze instructional materials for their effectiveness to teach inquiry (NRC, 1996). An examination of the course syllabus and the responses of the instructors on the interviews indicate that ePSTs were taught how to do this through assignments for evaluation of instruction materials available via the Internet. Interestingly, both instructors indicated that teaching ePSTs how to assess the suitability of instructional material for teaching science through inquiry was the hardest aspect of their instruction. Both instructors were apprehensive about the ability of the ePSTs to effectively evaluate instructional material to teach inquiry-based science given their limited pedagogical content knowledge and the knowledge of science content both of which are required for assessment of instructional materials as articulated in the response below:

> That's the hardest part involved with that because frequently they don't have a background understanding of content. For some of them, they're still at the point you teach process separate from content even though the standards say that these need to be merged. So they're more comfortable from a process perspective but trying to integrate . . . uh, we spent some time dealing with clarifying the standards, then, uh, from, uh, I think it's page 29 [of] the Inquiry National Science Education Standards we looked at . . . the variation of structure from a teacher as well as a student perspective for those five attributes. (P2)

However, most ePSTs indicated their intent to use inquiry-based instructional strategies because they themselves had positive experiences learning science through inquiry and because they understood the value of teaching and learning science through inquiry. The assertion that emerged from the analysis of the data was that, as a result of the inquiry-based pedagogies taught and modeled in the eSEM course, ePSTs understood the value of inquiry-based science instruction and were knowledgeable about the recommendations of the *NSES* for grades K-4 (NRC, 1996) for teaching and learning science through inquiry and, hence, were knowledgeable about inquiry-based pedagogy for teaching and learning science.

Preservice teachers received reinforcement of their understanding of inquiry-based pedagogies through their observations of science teaching during their science field experience which was taken concurrently with the eSEM course during the same semester. The majority of the ePSTs who participated in the focus group discussions indicated observing science and inquiry-based pedagogies for teaching science in the field. Preservice teachers reported that some of the inquiry-based science activities they observed in the field were similar to the ones they had been involved in during the eSEM course, indicating synergies in inquiry-based activities and pedagogy used in the field and those modeled in the eSEM course as indicated by the following response:

> I got to see the pendulum activity that we actually did in this class. (G4-S5)
>
> The notebooks of students in the field experience classrooms were organized with observations, data, asking questions, trying to answer questions, support with evidence, and predictions. Exactly like our notebooks. (G1-S4)

Thus, the majority of the ePSTs reported observing inquiry-based instruction both in the field and in the eSEM course and reported noticing similarities between science teaching strategies used in the eSEM course and those observed in the field. This was supported by the data from the SSQ which showed that the majority of the ePSTs (71.7%) indicated observing similarities between the science pedagogies modeled in the eSEM course and those they observed in the field. However, 19.1% of the respondents on this survey were not certain and another 9.2% were negative. The latter two categories might constitute responses of participants who indicated in the focus group sessions that they either had limited exposure or no exposure to science in the field, respectively.

There were multiple reasons why some of the ePSTs either did not observe or observed limited science teaching in the field. Some indicated that they did not observe science or inquiry in the field because they were placed in classrooms where science was not always being taught either because the grade levels did not require much science or because the time frame for their classroom observation did not coincide with the science period. Others indicated that their mentor teacher was busy teaching other subjects either because science was not a priority with their mentor teacher or because their mentor teacher sacrificed science to the multiple competing priorities posed by other subjects and standardized test preparation. The finding that some of the ePSTs reported not seeing or having limited exposure to science and, hence, inquiry-based pedagogy in the field might explain why some of the ePSTs responded on the SSQ either negatively or indicated being uncertain on the response category evaluating synergies between inquiry-based instruction modeled in the eSEM course and observed in the field. However, a clear-cut quantitative relationship cannot be made because while all 40 participants filled out the SSQ, not all of them participated in the focus groups. The assertion that emerges is that the majority of the ePSTs observed synergies between teaching strategies used in the eSEM course and those observed in the field. Thus, the findings indicate that ePSTs understood what constitutes scientific inquiry and inquiry-based pedagogies as recommended by the *NSES* for teaching and learning science through inquiry.

Discussion

Literature points out that under the reform-based curriculum, construction of an identity as a science teacher can be complicated due to the multifaceted nature of inquiry science teaching (Colburn, 2000; Hayes, 2002). However, most preservice teachers (ePSTs) in this study reported that the teaching strategies modeled and taught by the instructors and practiced by the ePSTs in the elementary science methods (eSEM) course and observed through the science field experience were beneficial to them for developing their own teaching strategies for their future careers as practicing teachers. This is consistent with findings reported in literature that engaging ePSTs in scientific inquiry-based courses not only leads to the development of their understanding of science and scientific inquiry but that it also helps prospective teachers become more accepting of approaches to teaching science that encourage children's questions about science phenomena (Haefner & Zembal-Saul, 2004). This has only been demonstrated in the context of an innovative life science course.

The majority of the ePSTs in this study welcomed the shift to inquiry-based pedagogy for teaching science as it allowed them to get away from the traditional textbook dependency as the main course of science information and transition to a more hands-on approach wherein students are central to the knowledge building and the learning process. They also reported understanding that the use of inquiry-based learning can help students gain confidence in science and retain knowledge better than if they are taught using a textbook. This perception of preservice teachers is consistent with reports in literature that inquiry-based teaching strategies and a greater emphasis on inquiry methods for the development of personal meaning in science can lead to higher student achievement in science (Anderson, 1997; Duran et al., 2004; Von Secker, 2002).

An unexpected but interesting benefit cited by ePSTs of the constructivist approach to learning science was in the area of classroom behavior management. Though this is a logical conclusion based on the knowledge about learning in a constructivist environment, it is contrary to at least one report in literature. In a study conducted to evaluate ePSTs' struggles to define inquiry-based science teaching, Hayes (2002) reported that ePSTs expressed concerns about maintaining control of the students during the open explorations required for inquiry-based learning.

Another interesting finding from this study was that even though initially most ePSTs indicated experiencing frustration with the inquiry-based, constructivist way of learning and wanted more direction from the instructors, toward the end of the eSEM course, most of the ePSTs developed a new appreciation for the value of the inquiry form of science instruction for student learning and valued the active learning experiences and opportunities, complimented the hands-off approach taken by the instructors, and indicated that inquiry-based instruction helped them construct their own knowledge. The finding that ePSTs moved from initial feelings of frustration in a constructivist learning environment to a feeling of acceptance and appreciation is also consistent with results reported in literature for specialized inquiry-based science content courses (Duran et al., 2004; Friedrichsen, 2001; Hayes, 2002; Jones et al., 1997; McLoughlin & Dana, 1999; Powell, 2003). It is therefore not surprising that some researchers are recommending that to teach inquiry to ePSTs, science teacher educators should target the fundamental aspects of scientific inquiry and problematize them for prospective teacher learning (Haefner & Zembal-Saul, 2004).

Data from this study indicate that ePSTs' apprehensions about teaching inquiry-based science were stemming from self-doubt about their own knowledge of science content, from the realization that inquiry-based instruction is more time-consuming and required additional effort and preparation time, and from their concerns about whether the traditional elementary school curriculum would provide adequate time or support for them to implement inquiry-based science teaching strategies, which is consistent with reports in literature that the current set-up of the elementary school curriculum does not afford teachers time or the support for teaching science consistent with recommendations of the *NSES* for doing science as inquiry (Abell, 2006; Abell & Roth, 1992). Literature indicates that the feeling of self-doubt for teachers considering new approaches to education, such as inquiry-based instruction, results from their dilemmas about change which could stem from the ePSTs' own beliefs, values, and goals being at odds with those that support inquiry (Andersen, 2002; Volkmann, Abell, & Zgagacz, 2005). The results from this study suggest that frustration and struggle with the scientific inquiry-based pedagogical experiences for ePSTs can be a very effective means of learning about scientific process and science. This is consistent with reports in literature that it is the struggles related to resolving these tensions that lead preservice or novice teachers to come to grips with their emerging identities as teachers (Goodfellow & Sumsion, 2000; Haefner & Zembal-Saul, 2004; Hayes, 2002).

Conclusion

Results of this study suggest that when multiple inquiry-based experiences, from guided to open inquiries, that challenge preservice teachers' learning in a constructivist environment are integrated into the elementary science methods course, ePSTs not only develop an understanding of inquiry-based science instruction but also develop an appreciation for the benefits of teaching and learning science through inquiry in a constructivist environment, indicating comfort with using inquiry-based science teaching strategies in their own classroom practice when they become practicing teachers. Additionally, having ePSTs concurrently involved in field experiences which reinforce inquiry-based science pedagogy taught in the elementary science methods course helps preservice teachers conceptualize their own pedagogy in science and helps them start defining and accepting their changing role as a facilitator as envisioned in the *NSES* (NRC, 1996, 2000). However, even though the majority of the ePSTs in this study indicated their intent to use inquiry-based strategies to teach science in their classrooms and even though there is evidence in literature suggesting that a mathematics methods courses can change preservice teachers' beliefs and attitudes to be more consistent with the current reform movement in mathematics (Wilkins & Brand, 2004), a follow-up study is needed to explore how many of these ePSTs actually incorporate inquiry-based science teaching into their classes.

This research study was limited in that it examined the perceptions of ePSTs regarding their understanding of scientific inquiry and inquiry-based science pedagogy after concurrently completing a traditional eSEM course and its associated science field experience at only one large Midwestern university campus. Not all campuses offer the eSEM course and the science field experience in the same semester. Also, this study did not examine the effect of gender, socioeconomic factors, or ethnicity on ePSTs' understanding of inquiry or inquiry-based pedagogy to teach science as all of the participants were White females from upper middle class backgrounds.

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Appendix I

Focus Group Protocol

1. What in your opinion constitutes a scientific investigation?

2. Describe some investigations that you or the professor/instructor conducted in the elementary science education methods course?

3. Describe **unique** aspects of teaching strategies you observed during your field experience or in the elementary science education methods course that will help you develop your own teaching strategies.

4. In your opinion, how does the inquiry-based instruction facilitate learning of science?

5. How has the elementary science education methods course helped you understand the inquiry form of science instruction and the way science should be taught?

6. How did your elementary science education methods course increase or decrease your confidence to teach science at the elementary level?

7. How are the strategies taught in the elementary science education methods course consistent with your view of inquiry?

8. Do you plan to use inquiry to teach science?

Appendix II

Interview Protocol

1. What science teaching strategies did you teach/demonstrate to the preservice teachers?

2. In your opinion what are the basic elements of inquiry-based instructional strategies?

3. How was the inquiry form of instruction demonstrated to the preservice teachers during the methods course?

4. How do the teaching strategies emphasized in the methods course relate to the *National Science Education Standards* for teaching science?

5. How does the methods course help preservice teachers learn scientific investigational techniques?

6. In what way are the teaching strategies taught in the methods course effective to teach inquiry skills?

7. How does the elementary science education methods course help preservice teachers learn to analyze instructional materials for inquiry as content?

8. How does the methods course help preservice teachers develop confidence to teach science?

Appendix III

Study Specific Questionnaire

Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters below each statement.

SA = Strongly Agree
A = Agree
UN = Uncertain
D = Disagree
SD = Strongly Disagree

1. Scientific investigations involve exploring questions generated by curiosity.

   SA A UN D SD

2. Describing objects/events and constructing explanations all constitute scientific inquiry.

   SA A UN D SD

3. Testing explanations of phenomenon and communicating findings to peers is **not** part of scientific investigation.

   SA A UN D SD

4. Scientific learning is usually a result of collaborative effort between students.

   SA A UN D SD

5. Findings and data of scientific investigations do not need to be recorded.

   SA A UN D SD

6. Allowing students to explore science concepts on their own does **not** result in learning.

   SA A UN D SD

7. As a science teacher, I should support student curiosity by giving students time to explore explanations of scientific phenomenon.

   SA A UN D SD

8. Scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world.

   SA A UN D SD

9. Different kinds of questions can be answered by different kinds of scientific investigations.

   SA A UN D SD

10. I feel more confident to teach science after taking the elementary science education methods course.

    SA A UN D SD

11. Overall the teaching strategies I observed in the science field experience are consistent with those taught in the elementary science education methods course.

    SA A UN D SD

12. The teaching strategies I observed in the field were very different than those taught in the elementary science education methods course.

    SA A UN D SD

13. Science teaching strategies used by cooperating teachers in my field experience to teach elementary science encouraged students to explore, observe, and challenge each other's findings.

    SA A UN D SD

14. The elementary science education methods course along with the science field experience has given me the confidence to teach science.

    SA A UN D SD

15. I feel more confident about teaching science after having gone through the elementary science education methods course and the science field experience.

    SA A UN D SD

16. Scientific explanations emphasize evidence; have logically consistent arguments; and use scientific principles, models, and theories.

    SA A UN D SD

17. Current scientific knowledge and understanding do **not** guide scientific investigations.

    SA A UN D SD

18. Researching information in reference journals, on the Internet, and in the library all constitute scientific inquiry.

    SA A UN D SD

19. Communicating, sharing, and reviewing each other's results are all a part of scientific inquiry.

    SA A UN D SD

20. The *National Science Education Standards* require students in K-5 to be able to ask questions, plan, and conduct simple investigations; employ simple equipment and tools to gather data; use data to construct reasonable explanations; and communicate investigations and explanations.

    SA A UN D SD