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Exploring Elementary Science Methods Course Contexts to Improve Preservice Teachers' NOS of Science Conceptions and Understandings of NOS Teaching Strategies

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We explored adaptations to an elementary science methods course to determine how varied contexts could improve elementary preservice teachers' conceptions of NOS as well as their ideas for teaching NOS to elementary students. The contexts were (a) NOS Theme in which the course focused on the teaching of science through the consistent teaching and learning about NOS in all course activities, (b) Reflective NOS Teaching in which the course focused on developing explicit and reflective practice regarding NOS during portions of the semester, (c) Problem-Based Learning context in which local problem-based science scenarios were used to teach about NOS in an explicit and reflective manner, and (d) NOS embedded into Authentic Inquiry in which the learning and teaching of NOS occurred in conjunction with completing a long term science investigation suitable for use in elementary classrooms. We found that all preservice teachers improved in their conceptions of NOS in all four contexts, but to varying degrees. Preservice teachers described different strategies for teaching NOS by context. Our results show many contexts can be used to improve conceptions about NOS and the teaching of NOS, but certain contexts may support the learning of particular NOS ideas and the teaching of those ideas better than others.

Keywords: Nature of science, elementary, pre-service teachers, situated learning

INTRODUCTION

Nature of Science (NOS) is considered a crucial component of scientific literacy in reform documents such as the Framework for K-12 Science Education (NRC, 2012), and the Next Generation Science Standards (Achieve, 2013), suggesting that teachers of all grade levels help K-12 students develop an informed understanding of NOS as a component of developing scientific literacy. However, several studies have indicated that K-12 students are not acquiring the necessary understandings of NOS outlined in these

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State of the literature

- It is clear that NOS can be taught through explicit reflective methods
- It is clear that preservice teachers can learn to teach NOS to elementary students
- What is not clear is how different methods instructors can embed explicit reflective instruction in different paradigms and the effects on preservice teacher knowledge of NOS and of teaching NOS

Contribution of this paper to the literature

- This paper explored four different science methods contexts to determine how varied contexts could improve elementary preservice teachers conceptions of NOS and ideas for teaching NOS may be influenced, using a multi-case study approach that included interviews, classroom observations and video recordings, researcher logs, collection of student work, and an independent researcher who was not an instructor and was therefore unbiased toward teaching strategy.
- All methods course instructors employed explicit reflective instruction but from different course context perspectives: (a) NOS Theme, (B) Reflective NOS Teaching, (c) Problem-Based Learning, and (d) NOS embedded in Authentic Inquiry. Preservice teachers in all contexts improved in their conceptions of NOS, but to varying degrees depending on NOS aspect and context.
- Preservice teachers in all contexts conceptualized strategies for teaching NOS to elementary students, again, dependent upon context, though some strategies were common across all contexts.

reform documents (e.g. Author, 2009; Bell, Blair, Crawford, & Lederman 2003). Moreover, research has shown that for students to sufficiently learn NOS teachers must have an effective understanding of it for themselves and an understanding of how to teach it (Abd-El-Khalick, Bell, & Lederman, 1998; Author, 2009, Matkins & Bell, 2007). Research has shown that through appropriate instruction preservice elementary teachers can improve their understandings of NOS (e.g. Akerson, Abd-El-Khalick, & Lederman, 2000; Lederman, 2007), and in some cases transfer their understandings to classroom instruction with support (e.g. Akerson & Volrich, 2006; Ozcal, Tekkaya, Sungur, Cakiroglu & Cakiroglu, 2011). Thus, further research is needed to explore various strategies for helping teachers (both preservice and inservice) to not only learn about NOS, but to learn how to teach it (Lederman, 2007). The purpose of our study is to provide insights into the kinds of NOS instruction that can be embedded successfully into methods courses to aid university faculty in helping teachers develop NOS teaching strategies. This study explores four different instructional approaches, or contexts, for preparing preservice elementary teachers to understand NOS as well as teach NOS to elementary students. The two research questions guiding our exploration were "What are preservice teachers' NOS conceptions after participating in one of four different science methods courses?" and "What are preservice teachers' perceptions of their NOS teaching strategies from participating in one of four different science methods courses?"

Emphasis on NOS

NOS is the epistemological and sociological view of what science is and how knowledge in science is developed. NOS is a way of knowing, or the values and beliefs inherent to scientific knowledge and its development, not to the practices of science or science process skills. An informed understanding of NOS enables an individual to acquire a deeper comprehension of science content, supports sound decision-making based on evidence, and can spark an interest for some to study science as a career (McComas, Clough, & Almazra, 1998). Within the research literature the following seven aspects are identified as key components of NOS and these aspects guided our understanding of what to teach in our methods courses. These are: (1) science is tentative; (2) it is based on empirical evidence; (3) there is a distinction between observation and inference when gathering and analyzing data; (4) interpretations of data is subjective; (5) the process and design of scientific investigations requires creativity; (6) there are social and cultural views embedded in one's interpretations; and (7) there is a difference but also a relationship between scientific theory and law (NSTA, 2000).

Developing NOS Conceptions and Teaching Strategies in Elementary Methods Courses

We have long known that scientific knowledge can be constructed in the science classroom through interactions of students with the teacher (Driver, Asoko, Leah, Mortimer, & Scott, 1994). Without appropriate conceptions of NOS teachers will not be able to influence their students' NOS conceptions (Sariedenne & BouJaoude, 2014). Indeed, it has been found that explicit reflective strategies used within elementary methods courses are effective in improving preservice elementary teachers' NOS conceptions (Akerson, Abd-El-Khalick, & Lederman, 2000). Prior studies have explored different methods for helping preservice teachers improve their conceptions of NOS and develop teaching strategies. For example, (Akerson & Volrich, 2006) explored a preservice teacher's ability to teach NOS in her internship setting and found that not only was she successful in conceptualizing NOS aspects herself, but she was able to teach these ideas to her elementary students. McDonald (2010) found that explicit NOS instruction through scientific argumentation was effective at improving preservice elementary teachers' conceptions of NOS. Scientific argumentation provided a good context for emphasizing NOS aspects in a science content course. Hammrich (1998) found similar results in a methods course that contextualized the NOS content into cooperative controversy challenges for preservice teachers.

Matkins and Bell (2007) explored context-based NOS by contextualizing NOS in science content about global warming. They found this contextualization of NOS in a current and controversial science phenomenon was effective in helping preservice teachers improve their NOS conceptions and develop an awareness of this critical socioscientific issue. Howe and Rudge (2005) used a medical science context to explore the influence on students' conceptions of NOS and found results similar to those of Matkins and Bell. The researchers called for more exploration and investigations of different contexts for teaching NOS explicitly.

Abell, Martini, and George (2001) used the concept of moon phases to teach explicitly about NOS in their preservice elementary methods course. They found preservice teachers could readily conceptualize NOS ideas, but were not able to connect these ideas to what scientists do. The researchers postulated they needed to make more explicit the link between what the preservice teachers were doing in the moon phase investigations to the kinds of investigations scientists do. This finding further illustrates the necessity of explicit NOS instruction in concert with discussion that contextualizes it within science content and practice.

In another study regarding NOS and context, Bell, Matkins and Gansneder (2011) compared explicit NOS instruction alone versus explicit NOS instruction connected to a socioscientific issue and found that preservice teachers made substantial gains in both cases. However, one area in which the contextualized participants improved was in their ability to apply their NOS knowledge to decision making. The researchers concluded that it is not necessary to contextualize NOS if the primary goal is to improve NOS conceptions, though it is desirable if one wishes the preservice teachers to apply their knowledge to decision making. The researchers recommend exploring other contexts for teaching NOS explicitly in methods courses to improve preservice teachers' conceptions and teaching practice.

This finding provides impetus for exploring more contexts for NOS learning that will aid preservice teachers in improving and retaining their NOS conceptions. Indeed, different learners may attain NOS understandings better from different explicit contexts, enabling them to better understand, retain, and then teach NOS to their own students (Akerson, Buzzelli, & Donnelly, 2008a, Akerson & Donnelly, 2008b). Methods course contexts that use explicit NOS instruction coupled with instruction in metacognitive awareness of teaching NOS to elementary students can better enhances preservice teachers' NOS conceptions as well as plans to teach NOS in their own settings (Abd-El-Khalick & Akerson, 2009). Based on these findings, all contexts explored in this study not only used explicit NOS instruction, but also emphasized developing preservice teachers' metacognitive awareness for teaching NOS through connections made to teaching NOS to elementary students. We explored a variety of contexts into which we included contextualized, decontextualized, as well as explicit and reflective NOS instruction to determine how NOS can be effectively included in different methods courses.

THEORETICAL PERSPECTIVE

We base our perspective on knowledge development within the framework of situated learning (Gee, 2004). Within any given context individuals can take on different identities; however, and we hoped our preservice teachers would develop an identity of a teacher of NOS. Although we recognize that teachers in the same context who receive similar support can end up teaching NOS differently (e.g. Authors, 2009), we still believe they should have an accurate understanding of NOS. Therefore, we expected to find similar conceptions of NOS but different perceptions of teaching strategies for teaching NOS within each context. We recognize that cognition itself can be situated within a context—the relationship between learners and properties of the environment (Brown, et al., 1989)—so we acknowledge that NOS understandings and ideas for teaching NOS can be situated within different contexts, and that some contexts may be better for improving certain NOS ideas and understandings of teaching strategies than others. Therefore our contexts served as spaces to situate preservice teachers learning about NOS, translate NOS ideas into practice, and to aid them in conceptualizing strategies for teaching NOS. Each context is described below and summarized in Table 1.

NOS Theme Context

We called this context "NOS Theme" because the instructor believed that all aspects of elementary science teaching could be approached through a NOS lens. Whether working with teachers or children, research-based NOS instruction guided her practice of teaching science. She explained further, "I use a combination of contextualized and decontextualized NOS when I teach what NOS is, and then teach how to connect it to the science content. The whole theme of the class is NOS—that is my context."

In this context she endeavored to model strategies for teaching NOS to children. She emphasized explicit NOS instruction through use of NOS posters (Akerson, Weiland, Pongsanon, & Nargund,, 2011) to debrief science lessons, children's literature, conversations during and after lessons, observation/ inference charts, and thinking about how to ask questions of students to direct their attention toward NOS in their explorations. Through decontextualized investigations such as cubes, tubes, and file folder investigation (see Lederman & Abd-El-Khalick, 1998) she hoped they would solidify their NOS conceptions, as well as see a model for teaching NOS to children. For example, during the cubes investigation she asked students to "talk about inferences and then talk about how scientists make inferences—justify what you think is on the bottom of the cube." Following a discussion about their understandings of NOS she lead a discussion on how to teach NOS to young students, with the preservice teachers offering suggestions such as "listen to their ideas," "make connections to the NOS ideas through discussions," "and "help them see when they are making observations and when they are making inferences."

The instructor also used children's literature to aid the preservice teachers to consider how to teach about NOS to children. For example, she used *"Boy, were we wrong about dinosaurs!"* (Kudlinksi, 2005). She asked preservice teachers to figure out how this book incorporates aspects of NOS. The preservice teachers spoke about tentative NOS as scientists' ideas about dinosaurs changed. They drew connections to empirical NOS as scientists used data to determine that dinosaurs might be warm-blooded. They connected observation and inference by thinking about the fossils as well as the bones that were found, enabling scientists to make inferences about the animals that must have existed. They thought about the role of subjectivity and creativity in determining what a dinosaur had been like, as scientists thought about current animals, where bones were found, and kinds of fossils that indicate at least some dinosaurs had feathers. They did not discuss social and cultural connections to NOS, so the instructor raised the point that early in the book the Chinese

Table 1. Comparison of contexts to teach NOS

Context	Aim of NOS context	Strategies to teach NOS
NOS Theme	Improving NOS views and teaching how to teach NOS to children	Decontextualized activities (Tubes, Cubes, File Folder) NOS poster Children's literature Explicit discussion on how to teach NOS Use of observation/inference charts Explicit discussion on re-service science teachers' understanding on NOS Designing NOS lessons
Reflective Teaching	Developing reflective thinking on science teaching and students' learning of science	Decontextualized activities (Tricky Track, Cubes and Tube) Debriefing NOS poster Contextualized activities (lighting a blub, properties of matter, gravity dropping different balls, reading on Pluto_ Reflective discussions Reflective writing to prompt thinking on NOS understanding and NOS teaching
Problem-Based Learning	Developing NOS views through PBL	Decontextualized NOS activities embedded in PBL (Tricky Tracks, *Earthlets,* Mystery samples) Use of NOS poster to facilitate NOS discussion Ill-structured PBL problem Written reflection on NOS evident in PBL exploration
Authentic Inquiry	Improving the perception of how to help children think like scientists	Authentic inquiry experience Assignments to reflect on how to teach NOS Assignments to reflect on NOS aspects evident in inquiry activities Explicit NOS discussions Connecting NOS with inquiry activities Reflective writing on NOS teaching philosophy

scientists inferred dragons from the bones. This inference was not made in our culture because we do not have a strong focus on dragons in our culture.

Another strategy used in this context was connecting NOS to science content. For example, in week five the preservice teachers engaged in an investigation to determine "which antacid is the best." Through this open inquiry they were able to make connections to tentative NOS (by recognizing that though the class data showed the "best" antacid, their recommendations could change if they included other antacids to test, or other definitions of "best antacid"). They made connections to observations and inferences and empirical NOS by noting that they were making observations of evidence of pH change after they added the antacids, and inferring the best antacid based on the pH change. They recognized that they were "creating" an understanding of the best antacid of the group through their investigations. They also talked about how their subjectivity played a role in how they predicted the "best" antacid in advance—through what they normally used themselves should they need an antacid. They discussed the social and cultural connection in terms of what different cultures may use as antacids, as well as what different cultures may consider the "best" antacid.

At the conclusion of the semester students designed a series of sixteen lessons to teach NOS to elementary students. The preservice teachers included a variety of strategies they had learned in class in their plans.

Reflective Teaching NOS Context

The focus of this course, taught by a doctoral candidate in science education, was on developing preservice teachers' reflective thinking about teaching science and students' learning of science. This context was different from the previous context in that the instructor asked her preservice teachers to reflect in writing about different aspects of NOS after each class investigation or inquiry versus focusing on all aspects of NOS each week. The instructor chose the reflective context because of prior research demonstrating the effectiveness of reflection in preservice teacher education (Abell & Bryan, 1997). Therefore, her context involved having her preservice teachers reflect on the modeled NOS lessons that she delivered and then reflect on their own NOS teaching. She stated, "Reflective practice is the main key for learning how to teach NOS. I will have them reflect as a group, then individually, to help them learn about NOS and teaching NOS. Talking with their peers will help develop their individual ideas. "

The instructor began her NOS instruction with decontextualized investigations to emphasize NOS without intimidating the preservice teachers who may have been insecure about their content knowledge. At the beginning of the semester, the instructor assigned readings related to NOS such as "Ten Myths of Science" (McComas, 1996), and, as stated previously, engaged preservice teachers in decontextualized NOS investigations to help them understand each aspect. Similar to the NOS Theme context, the instructor utilized the NOS poster (Akerson, Weiland, Pongsanon, & Nargund, 2011) to explicitly facilitate discussion to identify NOS tenets evident in each investigation, After three decontextualized lessons, preservice teachers were assigned their first written NOS reflection as homework, focusing on only one or two NOS aspects.

Contextualized NOS instruction began with an investigation consisting of four stations designed to develop understandings of various aspects of NOS within science content. In the first station, the instructor had preservice teachers explore scientific law through lighting a light bulb with a battery and a wire. She asked them to develop an explanation for why it did or did not hold true. She asked them to reflect in writing on the empirical evidence they used to build their explanations. The second station enabled preservice teachers to explore properties of matter through connecting the NOS aspects of observation and inference and empirical data. Preservice teachers responded in writing to the prompt "What observations and/or inferences will you need to make before, during or after to use as evidence to answer your question?" In the third station as preservice teachers explored gravity and reflected on these NOS ideas in writing. In the final station preservice teachers explored Pluto being demoted from planet status, connecting tentativeness as well as the subjective NOS. She asked the preservice teachers to reflect on "how would you help your class make sense of the change in Pluto's status? How will you help the child understand why some books they read say it is a planet while newer books do not?" The instructor had them record their ideas about content and NOS and as she monitored the class she asked them to raise questions at each station. At the end of the lesson she gave the preservice teachers a chart of NOS aspects and asked them to identify which of these were represented and where in each investigation. Finally, the preservice teachers completed their second NOS reflection regarding where they noticed the tentative nature of science in their investigation.

The second contextualized inquiry engaged preservice teachers in an investigation of cohesion and adhesion of a water drop on pieces of aluminum foil, plastic wrap, and wax paper and made observations and inferences about the water drops. They discussed whether and why those inferences might change if they tested more surfaces and then completed a reflection.

By week four of the semester, the instructor provided the preservice teachers less guidance in their reflections on NOS by asking them to think of their own ideas about NOS related to their investigations. To engage the preservice teachers in content related to buoyancy, the instructor facilitated a Cartesian Diver exploration. They completed their third NOS reflection individually, asking them to record their ideas about any NOS aspects they saw used.

Finally, the instructor engaged preservice teachers in two more inquiry-based lessons while examining aspects of NOS evident in each. She asked preservice teachers to explore light and shadows during a two-day lesson

Table 2. Codes for ıdentifying preservice teacher NOS conceptions in each context

NOS Aspect	Pre-Codes	Post Codes	Coding for Inadequate, Emerging, and Adequate Ideas of Each Conception
Tentativeness	Add-on: change with additional evidence/data Disprove: dump the theory for a new one Evidence required: need evidence to change a theory (either for adding on or reinterpreting)	*Add-on: change with additional evidence/data* *Disprove: dump the theory for a new one* *Evidence required: need evidence to change a theory (either for adding on or reinterpreting)* *Change all the time: Part of being "science" is that it changes all the time.* *Modify: Theories can be modified, not really changed.*	Inadequate: Scientific knowledge does not change. Emerging: Scientific knowledge changes "all the time" or changes only because of additional data Adequate: Scientific knowledge changes with new information or reinterpreting existing data.
Theory and Law	Law states relationship, theory describes relationship Law is proven, theory is not.	*Law states relationship, theory describes relationship* *Law is proven, theory is not.* *Theories are made up by scientists*	Inadequate: Laws never change; theory becomes law Emerging: Laws and theories change Adequate: Laws state a relationship, theories describe relationships
Creativity and Imagination	Science is Fact: Cannot use imagination or what you know what be "real" Use in conclusions: Interpreting data requires creativity Design: use in design, but then the evidence speaks for itself.	*Science is Fact: Cannot use imagination or what you know what be "real"* *Use in conclusions: Interpreting data requires creativity* *Design: use in design, but then the evidence speaks for itself.* *Explanations require it: Must use creativity and imagination to interpret data and develop explanations.* *Represent data: Use creativity to communicate evidence (e.g. nice power points, etc)*	Inadequate: Science is fact, no imagination. Use creativity to represent data. Emerging: scientists use imagination when designing only. Adequate: Scientists use imagination and creativity throughout an investigation.
Empirical	Experiments: Requires controlled experiment Technology: Technology is used to provide data Right/true answer: Empirical data gives you the right answer	*Experiments: Requires controlled experiment* *Technology: Technology is used to provide data* *Right/true answer: Empirical data gives you the right answer* *Science requires evidence:* *Science uses pictures and tools: collecting data* *Inferences are made: Infer explanations from evidence* *Builds on prior work: Use evidence to extend knowledge.*	Inadequate: Data gives you the one right answer and speaks for itself. You must see it to believe it. Emerging: Data helps you figure out scientific claims. Technology helps. Adequate: Scientists make direct or indirect observations of data and then make inferences about that data using their prior knowledge and understandings.

Table 2. Contionusly

Empirical	Experiments: Requires controlled experiment Technology: Technology is used to provide data Right/true answer: Empirical data gives you the right answer	*Experiments: Requires controlled experiment* *Technology: Technology is used to provide data* *Right/true answer: Empirical data gives you the right answer* *Science requires evidence:* *Science uses pictures and tools: collecting data* *Inferences are made: Infer explanations from evidence* *Builds on prior work: Use evidence to extend knowledge.*	Inadequate: Data gives you the one right answer and speaks for itself. You must see it to believe it. Emerging: Data helps you figure out scientific claims. Technology helps. Adequate: Scientists make direct or indirect observations of data and then make inferences about that data using their prior knowledge and understandings.
Subjectivity:	Individual interpretation: Each individual interprets data their own way Insufficient data: All would interpret the same way if there were enough data Purposely collect data: Scientists purposely collect and pay attention to specific data to answer their question (almost like rigging the study)	*Individual interpretation: Each individual interprets data their own way* *Insufficient data: All would interpret the same way if there were enough data* *Purposely collect data: Scientists purposely collect and pay attention to specific data to answer their question (almost like rigging the study)* *Beliefs/interpretations: Beliefs influence interpreting data* *Knowledge=fact* *Knowledge=evidence/data* *Opinion requires no evidence*	Inadequate: If there were enough data all would agree. Purposely looking only at data that supports individuals' claims. Emerging: Individuals interpret data differently. Adequate: Individuals interpret data differently due to differences in their background knowledge and personal understandings.
Sociocultural	Culture affects data interpretation: the individual's culture effects interpretation of data Background/prior knowledge: Background knowledge based on living in the culture effects data interpretation	*Culture affects data interpretation: the individual's culture effects interpretation of data* *Background/prior knowledge: Background knowledge based on living in the culture effects data interpretation*	Inadequate: Data speaks for itself Emerging: Culture affects interpretation of data Adequate: Culture affects data interpretation by influencing what "counts as science" and "what counts as important questions to explore"

that included objects that are transparent, translucent, and opaque, and how different shadows are formed. The prompt for this investigation was for preservice teachers to individually record their ideas about empirical data and observation and inference. The final investigation demonstrated the water cycle. Following this investigation the preservice teachers reflected individually in writing on their understandings of tentative NOS, and the distinction between observation and inference as well as scientific creativity.

Problem-Based Learning (PBL) Context

In this context the instructor was a doctoral candidate in science education. She engaged preservice teachers in decontextualized and contextualized instruction rooted in Problem Based Learning (PBL). She selected the PBL context because research had suggested that instruction, especially for English Learners, is more effective when presented in a context that includes students' interest and prior knowledge (Donovan & Bransford, 2005). Further, Akınoğlu and Tandoğan (2007) found that PBL had a positive effect on students' science attitudes and achievement. The instructor stated, "I utilized the main elements of PBL (Gallagher, Sher, Stepien, & Workman, 1995)—a major point being that the learning is rooted in an ill-structured problem, meaning there is no one answer, that PSTs can investigate through open inquiry. I demonstrated NOS explicitly through classroom discussion during the PBL." This context was different from the previous two contexts as it did not emphasize NOS aspects independently, but embedded within a problem.

As with the other contexts, the instructor began her instruction with decontexualized NOS lessons (see Table 1) and used the NOS poster used in the two previous contexts to facilitate a discussion of NOS aspects evident in the explorations. Next, the instructor asked preservice teachers to reflect on what they wanted to know more about regarding NOS content and NOS teaching. The preservice teachers wrote their answers on poster paper and shared them in "Gallery Walk" fashion.

Contextualized NOS instruction was embedded into a PBL unit. The instructor anticipated that the uncertain nature of an ill-structured PBL problem would allow for immersion of subjective and tentative NOS. Preservice teachers conducted their own investigations to examine the problem, which elicited observation and inference, creativity, and empirical NOS.

Preservice teachers were presented the following problem:

Do electromagnetic fields and radiofrequency cause a reasonable risk to human health? They then completed a three-column chart (Gallagher et al., 1995): What do we know? What do we need to know? How do we find out?. After the preservice teachers had collected their data, they analyzed it and formulated explanations using a claims/evidence chart. Finally, each group informally presented their results and each preservice teacher reflected on the NOS aspects evident in the PBL exploration.

Authentic Inquiry Context

In this context the instructor, a former elementary teacher and current assistant professor of science education, focused developing preservice teachers' pedagogical content knowledge for teaching inquiry-based science. She provided her preservice teachers with their own learning experiences of what constitutes inquiry-based science, as well as opportunity for reflecting on how to present similar experiences to children when teaching science. However, unlike the other NOS contexts, this instructor did not view NOS as an aspect of inquiry science that should be taught isolated from real investigations and science content. She stated, "My goal for teaching NOS is to teach several tenets of NOS by embedding them with learning about a scientific idea. To do this we must engage the [preservice teachers] in the practice of scientific inquiry." Furthermore, the Authentic Inquiry context differed from the PBL context because the instructor focused on inquiry for the sake of finding out information, not using inquiry to solve a problem.

The instructor used NOS as a reflective piece after lessons were taught. Her goal was not to teach NOS, but to teach content (e.g., how shadows are formed). Therefore, learning science content required an understanding of NOS and Inquiry practices collectively. Overall, she wanted preservice teachers to understand how to help children think like scientists—"to collect data, observe, make inferences, change their ideas as they learn more, or learn information that contradicts what they thought they knew. To use NOS to help them learn more about what inquiry is." She used specific NOS questions in her blog assignments so preservice teachers reflected on teaching NOS. She included NOS explicitly in the first nine weeks of the semester, but did not return to NOS instruction explicitly for the remainder of the 16-week semester.

During the second week of class she led students to explore NOS aspects the four stations described in the Reflective Teaching context. During the third week of the semester the instructor led a NOS discussion focusing on scientific evidence to make claims. She asked the preservice teachers to reflect on the stations from the previous week, and to reflect in writing on the NOS aspects that had been represented in the station explorations and what those were. During the second class session of that week they discussed their written reflections to the stations questions. The instructor talked about how the teaching strategies were explicit—that they were drawing connections from investigations at the stations to NOS through discussion and writing about their ideas, which is a form of explicit-reflective NOS instruction.

The following week the instructor held a discussion about observations and inferences, and how inferences are made from direct as well as indirect observations. She connected this to the setup of her long-term inquiry, Life in a Square (Park Rogers, 2009). In this inquiry, the preservice teachers mapped out a small square plot of land on campus and made observations and inferences of what was going on in that square over time. She did not emphasize NOS explicitly every week but did make explicit connection to tentative NOS when she held a discussion of how the preservice teachers made changes to their predictions about the plot they were studying based on the knowledge they gained from the data they were collecting.

She again connected the Life Square inquiry to NOS explicitly the week prior to the "Life Square Science Conference" which allowed preservice teachers to engage in an inquiry similar to that of professional researchers. Preservice teachers created posters of their investigative methods and results and discussed these results with their peers in a conference poster session format. Finally, As part of the portfolio submitted at the end of the semester the instructor required the preservice teachers to reflect on their NOS teaching philosophy through the prompt "What do you feel is your role, as an elementary teacher, in developing students' understandings of science content, process, and the nature of science?"

RESEARCH DESIGN

We used a multi-case study approach to explore different contexts (Bogdan & Biklen, 2003) within four undergraduate elementary science methods courses at a single university. We explored each methods course using the same research methods (described below) and tracked differences in NOS conceptions and understandings of teaching NOS that could be attributed to the context of NOS instruction. An outside person recruited participants from each class at the beginning of the semester, and though the class sizes were the same (24 per class) there are differing numbers of consenting participants from each class. Twenty-three preservice teachers in the NOS Theme context, fourteen in the Reflective Teaching context, sixteen in the PBL context and nine in the Authentic Inquiry context consented to participate in the research. The preservice teachers were juniors and concurrently enrolled in a field experience for teaching mathematics and science. All had similar content backgrounds from previously or concurrently taking the prerequisite physics, geology, biology, and chemistry courses.

Data Collection

Preservice teachers in the all four contexts responded to the Views of Nature of Science Form B (VNOS-B) (Lederman, et al, 2002) online using Survey Monkey prior to and at the conclusion of the semester to enable us to investigate any change in NOS conceptions. At the conclusion of the semester preservice teachers also responded to questions regarding their teaching of NOS as well as their plans for teaching NOS in their future classrooms. These questions were "Do you think NOS is important to include in your teaching, and why or why not?" and "How would you recommend including NOS in science teaching?"

Preservice teachers' course work (e.g., reflections and NOS-related assignments) was collected throughout the semester to enable tracking of NOS ideas over time. Course instructors maintained a teaching/research log of each class session recording insights into lessons of the day, as well as perceptions of NOS being discussed and learned in the class sessions and whether and how preservice teachers were including NOS in their lesson plans and instruction. These logs enabled us to track the amount of NOS instruction being included in each methods course.

An independent researcher, a doctoral student who was focusing her research on NOS, and was not an instructor observed and videotaped at least five class sessions for each course (two in the beginning, two in the middle, and one in the end), taking detailed field notes in each session. She also interviewed each class instructor for instructional goals and insights into teaching NOS and strategies for teaching NOS to preservice teachers. Her independent observations aided us in ensuring validity of our study, so that the researchers who were also instructors had an impartial eye in terms of delivery of NOS instruction as well as in analysis of preservice teacher understandings.

Data Analysis

To identify pre and post instruction NOS conceptions two researchers coded the VNOS-B responses gathered from each context, but not for their own context. These responses were coded by identifying patterns within the preservice teachers' responses to the questions. The patterns identified by the researchers were compared, discrepancies were discussed, and data were further consulted as needed. Table 2 shows the codes and descriptions of the ideas behind the codes that were identified in the data pre and post instruction and illustrates how we sorted the emergent codes into categories of inadequate, emergent and adequate NOS conceptions for each NOS aspect. Preservice teachers' NOS conceptions were compared pre and post in each context to note change in ideas over the course of the semester.

To identify conceptions of NOS teaching strategies two researchers searched for patterns in the preservice teachers' responses to the end of semester questions regarding teaching NOS in each context. To minimize bias, researchers did not analyze data from their own contexts. The researchers compared the strategies they identified and any discrepancies were resolved by discussion and further consultation of the data. These strategies were compared with course instructors' interview responses related to their intended NOS teaching strategies to determine the relationship between goals and what preservice teachers attained. Preservice teachers' work from each context was reviewed to compare these to their responses end of semester questions.

To track NOS teaching strategies in each course context the researchers again worked in teams of two to identify teaching strategies in videotapes of science methods instruction, researcher logs, preservice teacher work, interviews of methods course instructors, and field notes by the independent researcher. These codes were emergent and came from a review of the data of preservice teacher responses to two survey questions about ideas they had about the importance of and strategies for teaching NOS. Comparisons of these analyses were made by the researchers and "NOS teaching profiles" were made from the data, enabling a case to be presented for each methods course context that included methods course instruction as well as

NOS understandings and NOS teaching strategy understandings that developed in each context.

RESULTS

Given that explicit-reflective NOS instruction was employed in each context, preservice teachers in all contexts improved and refined their NOS conceptions, developed explanations for the importance of teaching NOS and ideas for strategies for teaching NOS. This finding is not surprising as explicit reflective NOS instruction has been found previously to be effective in improving NOS conceptions (e.g. Akerson, Abd-El-Khalick, & Lederman 2000). The main difference between the results of each context is the degree to which explicit and reflective NOS instruction was used and what was emphasized about NOS during science activities. The preservice teachers in different contexts held slightly different NOS conceptions, and described different strategies they could use for teaching NOS. Below we discuss these results in terms of context.

NOS Conceptions

Because there were a different number of preservice teachers who consented to participate in the research in each context, we report our results in percentages to enable easier comparisons across contexts. As can be seen from Table 3 preservice teachers in each context improved in their NOS conceptions of most NOS aspects by the conclusion of their methods course. It is also clear that these improvements were different depending on context of the methods course. We report the number of preservice teachers in each context who held specific conceptions of various NOS aspects in the paragraphs below.

Tentative NOS

Preservice teachers in different contexts had similar and differing ideas about NOS as was found in the emergent themes. For the tentative but reliable element NOS, in the NOS Theme context no students exited with inadequate conceptions, while 22% held adequate and 78% held informed conceptions. In the Reflective Teaching context 36% held inadequate ideas, 42% held adequate, and 21% developed informed ideas by the end of the semester. In the PBL context 6% held inadequate ideas, and 94% developed adequate understandings. In the Authentic Inquiry context 44% retained inadequate ideas while 56% held adequate understandings by the end of the semester. Regarding the tentative NOS, 20% of the preservice teachers in the NOS Theme context held an "add-on" view, while almost half of the preservice teachers in the Reflective Teaching context held that idea, (e.g., "theory can change based on new data or even new interpretations of prior data. The theories that we teach in school are theories that have been proven time and time again, and therefore are pretty solid, however they could change. This is why it is important to teach students that science is tentative and always changing"), whereas 25% of the PBL context, and 33% of the preservice teachers in the Authentic Inquiry context held such ideas. An example of an "add-on" view from the PBL context is, "Theories do change. They change because new information is found so the theory must be changed according to that new information." One preservice teacher in the Authentic Inquiry context held the idea that theories could be modified, but none in any other context mentioned this idea. This preservice teacher stated, "they change with new data and discoveries that don't fit with the current theory and then it will be modified." In the NOS Theme context 9% of the preservice teachers mentioned the influence of the scientists' opinions on the data as one reason for science being tentative stating, "Theories can change because we revisit the data, with new ideas, beliefs, and resolutions that allow us to understand and explain the world better. We change our ideas about what the data mean." This idea was not mentioned in other contexts.

Theory versus Law

There were similar differences regarding the distinction between theory and law. In the NOS Theme context 13% of the preservice teachers retained inadequate conceptions, while 87% held adequate understandings by the end of the semester. In the Reflective Teaching context 7% held inadequate understandings, and 93% developed adequate understandings. In the PBL context 50% retained inadequate understandings while 50% developed adequate understandings. The Authentic Inquiry context was similar to the PBL context with 44% retaining inadequate conceptions and 56% developing adequate ideas. No preservice teachers in any context developed informed understandings of the distinction between theory and law. However, no preservice teachers in the NOS Theme context held the inadequate understanding that laws are proven and theories can change, for example, one stated,

> *Scientific law is a statement of fact describing an action or series of actions, like Newton's law of motion. Scientific theory is an explanation of an observation or set of observations, like an explanation for why Newton's laws of motion work.*

Fifty percent of the preservice teachers in the Authentic Inquiry context, 25% of the preservice teachers in the PBL context, and two preservice teachers of the Reflective Teaching context held this idea. This finding indicates that the distinction between

Table 3. Comparison of pre and post NOS conceptions across contexts: percentage informed, adequate, inadequate

NOS Aspect	Level of Conception	NOS Theme (23 Participants) Pre	NOS Theme (23 Participants) Post	Reflective Teaching (14 Participants) Pre	Reflective Teaching (14 Participants) Post	PBL (16 Participants) Pre	PBL (16 Participants) Post	Authentic Inquiry (9 Participants) Pre	Authentic Inquiry (9 Participants) Post
Tentative	Inadequate	43%	0%	64%	36%	25%	6%	56%	44%
	Adequate	56%	22%	36%	42%	75%	94%	44%	56%
	Informed	0%	78%	0%	21%	0%	0%	0%	0%
Distinction between Theory and Law	Inadequate	91%	13%	57%	7%	94%	50%	56%	44%
	Adequate	9%	87%	42%	93%	6%	50%	44%	56%
	Informed	0%	0%	0%	0%	0%	0%	0%	0%
Empirical	Inadequate	82%	0%	71%	29%	56%	38%	89%	0%
	Adequate	17%	87%	29%	71%	43%	62%	11%	100%
	Informed	0%	13%	0%	0%	0%	0%	0%	0%
Creative and Imaginative	Inadequate	100%	0%	100%	36%	43%	12%	78%	78%
	Adequate	0%	100%	0%	64%	50%	82%	22%	22%
	Informed	0%	0%	0%	0%	6%	6%	0%	0%
Subjective	Inadequate	99%	4%	42%	29%	69%	13%	33%	11%
	Adequate	1%	74%	57%	71%	31%	75%	67%	89%
	Informed	0%	22%	0%	0%	0%	13%	0%	0%
Sociocultural	Inadequate	99%	51%	100%	50%	81%	63%	78%	78%
	Adequate	1%	49%	0%	50%	19%	37%	22%	22%
	Informed	0%	0%	0%	0%	0%	0%	0%	0%
Distinction between Observation and Inference	Inadequate	82%	0%	71%	29%	56%	38%	89%	0%
	Adequate	17%	87%	29%	71%	31%	62%	11%	100%
	Informed	0%	13%	0%	0%	13%	0%	0%	0%

theory and law requires more emphasis over time given the NOS Theme context emphasized all aspects of NOS each week. In the PBL context one student stated, "theory can change after scientists develop a theory. This is because science and data are always changing and can never be reliable or predictable," which is an inadequate view of science as ever-changing and unpredictable. Another shared an adequate view stating, "Scientific theory and scientific laws are very different kinds of knowledge. Scientific laws are generalizations, principles, or patterns in nature. Scientific theories are the explanations of these generalizations." In the Authentic Inquiry context a preservice teacher shared an inadequate idea that "Laws are undeniable. Theories are an idea backed by evidence and accepted by many people, like evolution. Theories can change. Laws do not."

Empirical NOS

Regarding the empirical NOS, in the NOS Theme context no students exited with inadequate ideas, with 87% developing adequate and 13% developing informed ideas. In the Reflective Teaching context 36% retained inadequate ideas, while 64% developed adequate ideas. In the PBL Context 38% retained inadequate ideas and 62% developed adequate ideas. In the Authentic Inquiry context 100% developed adequate ideas. There were no informed understandings of the empirical NOS in contexts other than NOS Theme. In the NOS Theme context all preservice teachers believed science was different from other forms of knowledge because it required evidence, stating the evidence could be collected through technology (35%), experiment (13%), collecting observations (30%) and making inferences (22%), and using background knowledge to interpret evidence (13%). One preservice teacher from the NOS Theme context stated,

> *scientists conduct investigations to make scientific claims. They make observations of their data, and of course, correlate these observations with their predictions and prior beliefs, and make an inference for the data. Like how they developed a model of the structure of an atom.*

In the Reflective Teaching context no preservice teachers mentioned experiments, though 29% mentioned the use of technology, 14% mentioned making observations, 7% mentioned making inferences, and 14% mentioned the importance of appropriate procedures, with one preservice teacher stating, "[Scientists] also construct the way they think [an atom] looks like based on the evidence they acquire."

Observations and Inferences

In the PBL context 50% of the preservice teachers mentioned the importance of making inferences from observations, 38% mentioned the use of technology to collect data, and 6% mentioned the importance of building on background knowledge to interpret data. For example, one preservice teacher stated, "The evidence [scientists] use is inferences based on their observations of what they can physically see with microscopes and their knowledge of what would probably be where they can't see." In the Authentic Inquiry context, all students mentioned the importance of experiments in developing scientific knowledge, along with 33% stating the importance of taking pictures or using tools when collecting data. One preservice teacher mentioned the importance of making observations, and none talked about building on prior knowledge. One preservice teacher in the Authentic Inquiry context stated "evidence is used, or real life experiments to figure something out." It is evident that in the NOS Theme and PBL contexts several preservice teachers connected various NOS aspects to the empirical NOS (e.g., observation and inference and subjectivity), whereas evidence of these connections made by preservice teachers in the Reflective Teaching and Authentic Inquiry contexts was not found.

Imaginative and Creative NOS

Regarding the imaginative and creative NOS, some preservice teachers in each context conceptualized that scientists were creative while interpreting results (NOS Theme: 100%; Reflective Teaching: 64%; PBL: 82%; Authentic Inquiry: 22%). In the NOS Theme context 100% of the preservice teachers developed adequate ideas about the imaginative and creative NOS. In the Reflective Teaching context, 36% retained an inadequate idea, while 64% developed an adequate understanding. In the PBL context 12% retained an inadequate idea, while 82% developed adequate understandings and 6% informed understandings. This is the only preservice teacher in all contexts who developed an informed idea of this NOS aspect. In the Authentic Inquiry context 78% retained an inadequate idea while 22% developed adequate understandings. Preservice teachers in the Authentic Inquiry context gave no other descriptions of when scientists may be creative or imaginative, but did agree they were creative, such as the comment by one preservice teacher "you have to interpret data, that is creative." Two preservice teachers in the Reflective Teaching and PBL contexts mentioned using creativity and imagination when communicating results. One preservice teacher in the Reflective Teaching context stated, "scientists have to be creative both during and after the collection of their data. They have to decide what data to report, how to report that data, and how to effectively communicate the data to others." A preservice teacher from the PBL context stated, "I think scientists use their creativity in many ways throughout the scientific process of experiments and investigations even after the planning and design processes. For example, they use their creativity in how they will share and present their data." In the NOS Theme context, preservice teachers also indicated a need for creativity and imagination when designing investigations and when raising new questions that come from the existing investigation. One student stated,

> *scientists use their creativity to figure out what their data means. If it comes out different from what they expect, they develop a new experiment or different way to test their hypothesis. They want to invent new ways to achieve different and accurate data and make good conclusions.*

Subjective NOS

Some preservice teachers in all contexts recognized that science was not fully objective, that there was an element of subjectivity due to individual interpretation of the data by the end of the semester (NOS Theme: 96%; Reflective Teaching: 71%; PBL: 88%; Authentic Inquiry: 89%). In the NOS Theme context 4% retained inadequate ideas, while 74% developed adequate and 22% developed informed ideas. In the Reflective Teaching context, 29% retained inadequate understandings, while 71% developed adequate ideas. In the PBL context 13% retained inadequate understandings while 75% developed adequate ideas and 13% developed informed ideas. In the Authentic Inquiry context 11% retained inadequate ideas while 89% developed adequate understandings. In the Authentic Inquiry context an additional four preservice teachers indicated an emerging conception that if the scientists had more data they would agree on the outcome, and one preservice teacher stated that they would not agree if there were missing data. One preservice teacher in the Authentic Inquiry context stated, "Science is based on observations and inferences, and is empirically based. Scientists may observe different aspects of the experiments and they could make different inferences about the experiments and read different conclusions, especially if they are missing data."

Indeed, 4% of the preservice teachers in the NOS Theme context also indicated that missing data would cause scientists to disagree on claims, while 13% discussed the importance of thinking about scientists' purposes for the data as a reason they may disagree.

Table 4. Importance of teaching NOS and NOS strategies in each context

Context	Importance of Teaching NOS	Strategies to teach NOS
NOS Theme (23 preservice teachers)	What science is/See how science works (23%) NOS is a part of science (17%) Provides strong basis in science (13%) NOS should be included in all science content (4%)	Including NOS in science content (100%) Use of NOS poster (96%) Children's literature (78%) Authentic experiences/Hands-on inquiry (35%) Activities (17%) Explicit discussion (4%)
Reflective Teaching (14 preservice teachers)	What science is/See how science works (14%)	Authentic experiences/Hands-on inquiry (50%) Including NOS in science content (36%) Working in groups (14%) Explicit discussion (14%) Activities (14%) Science Journals/Notebooks (7%)
Problem-Based Learning (16 preservice teachers)	What science is/See how science works (19%) NOS should be included in all science content (13%) NOS is a part of science (6%) Provides strong basis in science (6%)	Authentic experience/Hands-on inquiry (50%) Activities (38%) Science Journals/Notebooks (25%) Open inquiry/allow students creativity (25%) Explicit discussion (6%) Poster (6%) Children's Literature (6%)
Authentic Inquiry (9 preservice teachers)	What science is/See how science works (89%) Provides strong basis in science (11%)	Authentic experience/Hands-on inquiry (78%) Activities (22%)

Fifty-two percent of the preservice teachers in this context also indicated that scientists' opinions of the evidence would influence scientific knowledge. For example, one preservice teacher stated,

> *scientists are individuals, bringing in their own information and prior knowledge to add to interpreting experiments and data. They have different ideas based on how they view … read …, and answer according to the evidence. This is all based on their beliefs and knowledge of the topic, along with how they think the results came up as they did. Scientists can have different beliefs and notions about the same sets ofdata. Scientists often need to argue their interpretations of data in order to make specific claims.*

In the Reflective Teaching context, 7% of the preservice teachers indicated that a scientist could be biased and that is why that scientist would have disagreements with others. One other preservice teacher shared a more accurate view, stating, "Scientific knowledge is also influenced by your opinion, as it is impossible to be objective because of our prior knowledge and individuality. Your opinion is influenced by scientific knowledge as well." Twenty-nine percent of the preservice teachers in this context discussed the importance of using evidence, and how opinions of that evidence can influence scientific claims. In the PBL context 6% of the preservice teachers simply stated that scientists would certainly have different interpretations given that science itself is tentative, while 19% stated that scientific claims are different because science is subjective. One preservice teacher in the PBL context stated, "Everyone interprets data differently. One person can see one thing while another can see another thing." Therefore preservice teachers were making connections among NOS aspects.

Sociocultural NOS

Regarding the sociocultural NOS, some preservice teachers in all contexts acknowledged the influence of the scientists' background knowledge on the interpretation of data (NOS Theme: 49%; Reflective Teaching: 50%; PBL: 38%; and Authentic Inquiry: 22%). In the NOS Theme context 51% retained inadequate ideas while 49% developed adequate ideas. Similarly, in the Reflective Teaching context 50% retained inadequate ideas while 50% developed adequate ideas. In the PBL Context 63% retained inadequate ideas while 38% developed adequate understandings. In the Authentic Inquiry context there was no change pre to post, 78% retained inadequate understandings while 22% retained adequate understandings. No preservice teacher in any context developed informed ideas about sociocultural NOS. In the Authentic Inquiry context no preservice teacher indicated any other reasons for different interpretations of data, with one preservice teacher stating, "Prior knowledge and past experiences can affect the ways data is analyzed and account for the differences in beliefs among scientists." However, in the other three contexts preservice teachers also acknowledged the influence of the scientists' cultures on the interpretations of data (NOS Theme: 22%; Reflective Teaching: 14%; PBL: 19%). For example, one preservice teacher from the NOS Theme context stated,

science is a subjective field and scientists come from many cultures and family backgrounds and have different ideas... When they look at data they bring in their knowledge from their cultures and cultural bias into the interpretation.

Perceptions of NOS Teaching Strategies

Preservice teachers in all contexts were able to describe reasons they believed that NOS was important to include in science teaching. See Table 4 for their perceptions of the importance of teaching NOS as well as the NOS teaching strategies they identified by context.

Fourteen percent of the preservice teachers in the Reflective Teaching context indicated they thought NOS was important to include to help their students understand what science is and to see how science works. Preservice teachers in that context did not share other reasons, however preservice teachers in the other contexts agreed, with 26% from the NOS Theme context, 19% from the PBL context, and 89% from the Authentic Inquiry context indicating the same reason of importance. In addition, 22% of the preservice teachers in the NOS Theme context indicated that NOS is part of science content with one of those stating that it should be taught in all science content. One preservice teacher illustrated this idea through the statement,

"NOS is part of all science content. If you don't include it as part of your science every day you risk your students developing misconceptions about what science is. If they don't know what science actually is then how can they know whether they like it, and whether they want to be a scientist?"

Thirteen percent of the preservice teachers in that context indicated that NOS provides a strong basis for science, so students will be able to conceptualize what science is as well as the content of science. Similarly, 19% of the preservice teachers in the PBL context indicated that NOS is important because it is part of all science content, with two of those preservice teachers indicating it should be taught in conjunction with all science content. For example, one preservice teacher stated, "If you teach NOS students gain a better understanding of what science is. It is incorporated in all science so should be included in all science teaching." One additional preservice teacher in the PBL and Authentic Inquiry contexts also indicated that NOS provides a strong basis for science as it helps students conceptualize what science is as well as the content of science. For example, a preservice teacher in the Authentic Inquiry context stated,

It is important to teach NOS because students need to have an understanding of what science actually is. Students should explore NOS through investigations. The teacher should have a clear understanding of NOS so they may effectively touch on these concepts in class.

The NOS strategies that were reported by preservice teachers were context-dependent, with preservice teachers in each context describing strategies they would use with their students that had been used with them in their science methods courses. For example, in the NOS Theme context, all preservice teachers said they would relate every science inquiry in their class to NOS, using hands-on investigations and inquiry (52%), NOS posters to debrief the explorations (87%), and children's literature (35%), and mentioning the importance of debriefing NOS through explicit discussion (4%). These preservice teachers provided examples for teaching NOS aspects. One preservice teacher in the NOS Theme context shared the following strategy,

First, a teacher needs to teach about the NOS aspects, in connection with science.

Then the teacher needs to have students reflect on the NOS they see in each exploration. Like after an investigation on Oobleck the students can be asked to describe not only characteristics of solids and liquids, but also characteristics of science—e.g. the NOS.

In the Reflective Teaching context 50% of the preservice teachers said they would use hands-on investigations with 14% stating they would have students working in groups, and 36% indicating they would include NOS in all science. Fourteen percent of the preservice teachers indicated they would use explicit discussion of NOS while students reflected, as illustrated by this comment,

To help students understand NOS it needs to be part of active science investigations.

Plus the teacher needs to help the students reflect on NOS that is part of those investigations, either verbally or in writing.

In the PBL context 75% of the preservice teachers talked about making NOS a part of the daily science classroom through authentic experiences or open inquiry, with 6% indicating the importance of facilitating explicit discussions of NOS aspects. Twenty-five percent indicated the importance of using science notebooks or journals to model learning about NOS, while 6% noted the importance of children's literature and 6% noted the use of a NOS poster in debriefing inquiries. One preservice teacher in the PBL context stated,

NOS should be part of daily science teaching—with a NOS poster to help debrief, help students make connections through examples, modeling, and the teacher facilitating…social and cultural context influences the students, and I will help them understand this during making decisions about data.

In the Authentic Inquiry context only one preservice teacher stated NOS should be taught explicitly, while all recommended authentic science inquiries or investigations through which students would develop an understanding of NOS without naming NOS aspects. One preservice teacher from the Authentic Inquiry context stated, "NOS should be taught through inquiry and problem solving so their ideas stick. It is not so critical that students can name every aspect of NOS, but their overall understanding of science will be enhanced by understanding them."

DISCUSSION

Prior research indicates that NOS is best learned through an explicit reflective approach (e.g. Akerson, Abd-El-Khalick, & Lederman, 2000), which all contexts emphasized, but in different ways. Our current research suggests that the methods course instructor can select various contexts and degrees of emphases for teaching NOS explicitly that build on the course instructor's and preservice teachers' interests and feel confident that the preservice teacher will learn NOS as well as learn strategies for teaching NOS. These contexts and interactions within the contexts enable the instructor to situate the learning of NOS within elementary science content (Gee, 2004), and help preservice teachers improve understandings of NOS and develop strategies for teaching it to elementary students. It is interesting to note that the preservice teachers did learn strategies for teaching NOS from each context, and those strategies were the ones used by their methods instructors, further illustrating the role that the situation has on what is learned (Brown, 1989). Below we discuss the results in terms of preservice teachers' NOS conceptions and NOS teaching strategies.

Development of NOS Conceptions in Each Context

The results of this study highlight the kinds of differences in NOS conceptions preservice elementary teachers may develop as a result of participating in elementary science methods courses that have different emphases. According to our results, if one wants preservice teachers to have a more robust understanding of the distinction between theory and law, it seems that a PBL format or revisiting theory and law over time by creating a NOS Theme in your methods course will provide the kinds of experiences that will support those understandings for more preservice teachers. The relationship between scientific theory and law is not something with which many preservice elementary teachers have much experience. Indeed, if they do have experience with the ideas, it may be from inaccurate conceptions portrayed in science textbooks that describe scientific theories becoming scientific laws (McComas, 1996). In the PBL context as preservice teachers explored electromagnetic radiation they also examined an authentic example of scientific theory and law in depth. This in-depth exploration of theory and law embedded in science content may have helped them to more clearly see the relationship and how each type of scientific knowledge is based on evidence. This result is similar to the Matkins and Bell (2007) finding that an authentic issue, in their case global warming, was an effective context for improving NOS conceptions for preservice elementary teachers. In the NOS Theme context, the relationship between theory and law was consistently reinforced throughout the entire semester, aiding preservice teachers in better conceptualizing the ideas. This finding is supported by prior research that has shown that inservice teachers who spend more time learning about NOS and strategies for teaching NOS are better able to conceptualize NOS aspects that are emphasized (e.g. Abd-El-Khalick & Akerson, 2009). Our finding that preservice teachers had similar conceptions of theory and law whether in the NOS Theme context or the PBL context coincides with Bell, Matkins and Gansneder (2011) who found that preservice teachers in a socioscientific issues course and those in an NOS Theme course both held similar conceptions of NOS after instruction, and held similar abilities in applying their understandings to new situations. Moreover, our findings provide further support that it is not necessary to embed NOS into a PBL if the primary goal is to improve NOS conceptions; however embedding NOS into PBL can certainly provide other instructional advantages, such as to aid preservice teachers in their abilities to apply knowledge to scientific problems, which is also supported by Bell, et al. (2011).

The Authentic Inquiry context provided preservice teacher multiple opportunities to conceptualize using tools in collecting empirical data, while the NOS Theme course influenced more preservice teachers in noticing the distinction between observation and inference in collecting empirical data. The Authentic Inquiry context required preservice teachers to collect their own data, as well as to make inferences about that data. The NOS Theme course required preservice teachers to record data and draw distinctions between observations and inferences in a written form every week during in-class investigations. The Reflective Teaching context was a good strategy for aiding preservice teachers to conceptualize observation and inference, possibly because the course instructor emphasized this NOS aspect through discussion and writing prompts connected to course investigations. Though there was an improvement in conceptions of the empirical NOS and the distinction between observation and inferences in the PBL context, the improvement was less pronounced. This difference could be attributed to the fact that, due to the nature of the PBL question, preservice teachers spent more time researching through documents and positions about electromagnetism rather than directly collecting data themselves.

The tentative NOS seemed most readily conceptualized in the PBL context as well as the NOS Theme context. It is likely that the preservice teachers in the NOS Theme context developed improved conceptions more readily because this NOS aspect was repeatedly emphasized explicitly throughout the entire semester in the context of each investigation. Regarding the PBL context, it is likely that preservice teachers recognized that despite reading the same resources regarding the problem they were exploring, others in their class had different viewpoints regarding the scientific issue of electromagnetism. This demonstrates the socioscientific component of many science issues and noticing others' different conceptions could have influenced their own ideas and interpretations to change, illustrating the tentative NOS through the class explorations. The Reflective Teaching and Authentic Inquiry contexts were similarly effective at helping preservice teachers improve their ideas about the tentative NOS, but not to the same level as the PBL or NOS Theme. For the Reflective Teaching context this difference could be attributed to asking preservice teachers to reflect on a given aspect of NOS, rather than reflecting on all aspects of NOS after each inquiry or investigation. For the Authentic Inquiry context the difference may be attributed to each group of preservice teachers designing different inquiries during the Life in a Square project. It may be that if they were all working on the same inquiry they would come to differing interpretations of those inquiries and thus, better realize that their inferences may change as they compare others' results.

NOS Theme, Reflective Teaching, and PBL also seemed to be a good venue for developing conceptions of the creative NOS. There was no change in conceptions of scientific creativity for preservice teachers in the Authentic Inquiry context by the end of the semester. Again, we recognize that the NOS Theme context provided the most NOS instruction and postulate that is why the preservice teachers more readily conceptualized scientific creativity in that context. In the Reflective Teaching context the instructor explicitly asked preservice teachers to reflect in writing how they were creating scientific understandings through their investigations at several points in the semester, which contributed to their improved conceptions, however, only once were they given a prompt to explicitly reflect on the creative NOS. In the PBL context little guidance was offered as preservice teachers experienced for themselves the need to be creative in designing an investigation, formulating explanations based on data, and presenting their findings to their peers. It is unclear to us why there was no change in conceptions of scientific creativity for preservice teachers in the Authentic Inquiry context, particularly given the preservice teachers in that context created their own scientific investigations, and collected and interpreted their data. Perhaps a stronger connection can be explicitly made to how designing, carrying out, and interpreting investigations are all examples of scientific creativity, or perhaps the instructor's directions and guidance during investigation caused the preservice teachers to believe little creativity was involved.

PBL and NOS Theme most influenced informed conceptions of subjective NOS, with Authentic Inquiry and Reflective Teaching supporting adequate conceptions. From these results it seems that most preservice teachers in all contexts were able to conceptualize the subjective NOS. Perhaps this finding is due to the preservice teachers in each context recognizing that they were interpreting the data through their own understandings of the content and through their understandings gained through the resources they were reading, and were using these understandings to inform their claims. This recognition of the role of self in the development of scientific knowledge could contribute to an improved conception of the subjective NOS.

On the other hand, the sociocultural NOS was found to be the most difficult NOS aspect for preservice teachers in all contexts to grasp. Less than half of the preservice teachers in any context developed an adequate understanding of the sociocultural NOS, with preservice teachers in the Authentic Inquiry context exhibiting no change in conceptions by the end of the semester. Prior research has shown that this aspect is one of the more abstract and more difficult conceptions to change (e.g. Lederman, 2007) and while disappointing, this result is not surprising. More research could be conducted to determine other contexts strategies to use within contexts to improve conceptions of the sociocultural NOS.

Certainly a methods course instructor could choose to incorporate all the strategies and emphases within the course of a semester, and perhaps preservice teachers would not only strengthen their conceptions of NOS but also develop a wider repertoire of teaching strategies. Results indicate, however, that each context was successful in developing preservice teachers' conceptions of NOS and the need for teaching NOS to some degree. Therefore methods instructors can focus on other important science education ideas within their classes, and still be assured that their students can also gain understandings of NOS and NOS teaching strategies. We recognize that methods teachers have their own strengths and interests, and often experience time constraints within the methods course. We therefore believe that teaching NOS within different contexts is an appropriate approach to the methods course.

Development of Perceptions about NOS Teaching Strategies in Each Context

Preservice teachers in all contexts conceptualized the importance of teaching NOS within their elementary classrooms, providing similar reasons across contexts. This is not surprising given all course instructors explicitly emphasized NOS as being "what science is" or the "characteristics that make science 'science'," which was the most commonly given reason provided by preservice teachers in each class.

Along with developing a reason and purpose for teaching NOS, preservice teachers in each context were able to describe strategies they could use for teaching NOS in elementary classrooms. Though this study did not explore their implementation of NOS teaching strategies, we did find that all preservice teachers were able to describe various strategies they could use to teach NOS when they were teaching in the future. Not surprisingly, in the contexts that used the greatest number of strategies for teaching NOS to them (NOS Theme, Reflective Teaching, and PBL) the preservice teachers were able to provide more examples of ways to teach NOS in their elementary classrooms. The preservice teachers in the Authentic Inquiry context were able to describe ways to teach NOS through inquiry and investigations, but did not provide other suggestions. This result is not surprising given the other contexts used examples of debriefing NOS verbally, through writing, using a NOS poster, and through children's literature during the semester, all of which were mentioned by preservice teachers in these contexts.

The preservice teachers learned what was taught in terms of methods shared for teaching NOS in each context. They most commonly cited and described strategies for teaching NOS that they experienced as learners of NOS. For example, the preservice teachers who experienced learning about NOS through children's literature were able to describe that strategy as one to be used with children in the future. We believe that modeling NOS teaching strategies with the preservice teachers can support their understandings for how to implement and embed NOS into their science instruction. Perhaps adding a few more strategies for teaching NOS to the Authentic Inquiry context would broaden their ideas for how to include NOS within their science teaching.

Implications for Elementary Science Teacher Education

From our results we can state that if a methods course instructor's objective is to teach the aspects of NOS than they should focus mainly on explicit reflective NOS instruction throughout the semester. However, it is also clear from our research that explicit reflective NOS instruction can be embedded into different methods course contexts and will help preservice teachers better conceptualize NOS aspects as well as develop strategies for teaching NOS to elementary students. Preservice teachers in the NOS Theme context did not obtain ideas about using PBL or Authentic Inquiry in their elementary classrooms to the same extent as those preservice teachers who participated in those contexts. And preservice teachers in those contexts improved their conceptions of most NOS aspects. Our recommendations are to embed explicit reflective NOS instruction into all methods courses and all contexts and see how preservice teachers' conceptions and ideas of NOS teaching strategies develop. It is always the case that due to limited instructional time choices must be made about what to include in a methods course. However, it is clear that NOS can be effectively embedded in many methods contexts.

It could be the case that a variety of contexts could be used within a single methods course, exposing preservice teachers to different strategies, such as PBL, Authentic Inquiry, Reflective Teaching, among others, while embedding explicit reflective NOS instruction throughout the course. In that way preservice teachers would gain understandings of more teaching strategies at large, and could also improve their NOS conceptions and ideas for teaching NOS in their elementary classrooms. Instructors with varying expertise and emphases within their methods courses can embed NOS aspects in an explicit reflective fashion, and influence their preservice teachers' conceptions of NOS. Instructors who want their preservice teachers to know or be able to describe various strategies for teaching NOS should use more strategies to emphasize NOS in their own science methods courses as a model.

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