Int J of Sci and Math Educ (2017) 15:293–312
DOI 10.1007/s10763-015-9690-x

Exploring the Use of Lesson Study to Develop Elementary Preservice Teachers' Pedagogical Content Knowledge for Teaching Nature of Science

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Received: 29 May 2015 / Accepted: 6 October 2015 / Published online: 29 October 2015
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Abstract This study explored a modified version of Japanese Lesson Study to determine whether and how it influenced preservice elementary teachers in their abilities to deliver science lessons that included nature of science (NOS) to their own students. We used a case study approach that focused on one subset of a cohort of preservice elementary teachers within their field placement settings. Data sources included lesson plans, lesson feedback forms, videotapes of delivered lessons, and videotapes of lesson study feedback sessions. Early in the semester peers provided feedback on content, and later in the semester peers provided feedback on classroom management as well as content during the lesson study feedback sessions. We found that preservice elementary teachers were able to provide feedback to their peers regarding how to include NOS in their science lessons, yet did not naturally included NOS connections within their own lessons.

Keywords Elementary · Lesson Study · NOS · PCK · Preservice

Introduction

Nature of Science (NOS) is considered a crucial component of scientific literacy. The Next Generation Science Standards (NGSS Lead States, 2013) and the National Science Teachers Association (NSTA) position statement on NOS (2000) suggest that teachers of all grade levels should help students develop informed understandings of NOS in developing scientific literacy. However, most K-12 students are not acquiring necessary

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understandings of NOS. Moreover, research has shown that for students to sufficiently learn NOS that teachers must have good understandings of NOS and of how to teach it (i.e., Pedagogical Content Knowledge for NOS teaching) (Abd-El-Khalick, Bell, & Lederman, 1998; Akerson, Cullen, & Hanson, 2009; Lederman, 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), and transfer their understandings to classroom instruction (e.g. Akerson & Volrich, 2006). This study explores ways to help preservice teachers translate understandings of NOS into classroom practice, so they may enable children to conceptualize NOS.

Conceptual Framework

There are two key concepts guiding the design of this study. First is the understanding that NOS comprises epistemological and sociological views of how science is conducted and how knowledge in science is developed. Conceptualizing NOS translates to exploring a way of knowing, or the values and beliefs inherent to scientific knowledge and its development. An informed understanding of NOS enables an individual to acquire a deeper comprehension of science content, supports sound decision-making based on evidence, and perhaps even sparks an interest for some to study science as a career (McComas, Clough, & Almazra, 1998). Within the research literature, there are seven aspects identified as non-controversial components of NOS that are attainable by K-12 students. These aspects are included in the NSTA Position Statement (National Science Teachers Association, 2000) on components of NOS for K-12 classrooms and are in line with recommendations from Next Generation Science Standards (NGSS Lead States, 2013). We focus on these aspects recommended by these documents because our preservice teachers are working directly with children in the classroom. The aspects include: (a) science is tentative but reliable; (b) science is based on empirical evidence; (c) there is a distinction between observation and inference when gathering and analyzing data; (d) interpretation of data is subjective; (e) the process and design of scientific investigations requires an element of creativity; (f) there are social and cultural views embedded in one's interpretations; and (g) there is a difference but also a relationship between scientific theory and law. While there is some disagreement on what these aspects should be called, or whether these aspects are sufficient to elementary students (e.g. see Matthews, 2012), these ideas about the very nature of scientific knowledge are non-controversial and have been shown to be attainable by students as young as kindergarten (Akerson & Donnelly, 2010). As such, we chose to focus on the aspects of NOS that have had previous success in the research literature as being attainable by elementary students. Regardless of whether one calls these aspects *features of science* or aspects of *nature of science*, they are still worthy of instruction and research, and indeed, are still to be emphasized in USA science classrooms according to current reform documents.

Similarly, there are those who theorize that other approaches toward NOS instruction should be considered, such as a *family resemblance approach* (Irzik & Nola, 2011). According to this approach we should be teaching general methodology of science, even inquiry of science and then also noting where different sciences (or families) differ, such as archeology and zoology. However, we are talking about elementary students, and actually teaching them what science is, and is not. In this case, we need ideas about science that are attainable, and not ideas that are debatable. Another theoretical recommendation is to consider the Nature of (Whole) Science (Allchin, 2011). Accordingly, researchers should use authentic assessments of students to determine students' *whole science* views, similar to *whole foods* where nothing is left out. There would be no ideas about science targeted, but instead many ideas about science would be taught (and assessed) in a *whole science* way. Indeed, the assessment tool is quite long, and is intended to be used as the researcher watches the students engage in science and then interprets what must be their NOS understandings. However, simply engaging in science, or watching someone engage in science, certainly cannot tell the observer what that person conceptualizes as science, and we would argue, especially if that person is an elementary student. Also, presuming that engaging in science actually teaches one an accurate understanding of the very nature of scientific knowledge goes against the empirical research that exists that has illustrated that NOS must be explicitly taught. And again, how can all science be taught in an elementary school?

The second concept guiding this study is the notion of pedagogical content knowledge (PCK). This idea is an "amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding," (Shulman, 1987, p. 8). It is a professional knowledge base that transforms subject-matter knowledge into a way of knowing that is accessible to learners, and it is this knowledge base that separates teachers from content experts (Shulman, 1986). Although there are several knowledge components (Magnusson, Krajcik, & Borko, 1999) that inform the development of PCK (e.g., knowledge of learners of science, knowledge of instructional strategies, knowledge of curriculum, and knowledge of assessment), there are other factors that influence how teachers process information related to these knowledge components. These factors include teachers' orientations toward teaching science, subject matter understandings, pedagogical knowledge, and understandings of supports and limitations of the teaching context (Abell, 2007). For our study, we focus on how preservice teachers' knowledge for teaching NOS is shaped by their experience with collaborative planning, teaching, and reflective practice through modified lesson study.

Our study explored the use of a modified version of Japanese Lesson Study (Lewis & Tsuchida, 1998), as a tool for collaborative planning and reflective practice. This strategy takes place during the students' weekly field experience when they are teaching and reflecting on their teaching in elementary classrooms. We believe reflection is a critical component of developing PCK (Akerson & Donnelly, 2010), and it is from this stance that we explored the question "What influences might there be on preservice elementary teachers' PCK for teaching NOS as they reflect on their teaching of NOS through participation in a modified version of Japanese Lesson Study?"

Literature Review

We review the literature that has informed the design of our program and study. We review research that used forms of lesson study, studies to improve preservice elementary teachers' NOS instruction, and the development of preservice elementary teachers' PCK for NOS.

Why Use Lesson Study for Developing NOS PCK

Many researchers have emphasized the positive impact of teaching experience and reflection on the development of preservice teacher's PCK. For instance, Bryan and

Abell's (1999) case study investigated the transformation of one preservice teacher's beliefs about science teaching and learning over the course of 1 year. During the participant's student teaching semester, each teaching session was videotaped and analyzed by the participant during interviews with the researchers. Bryan and Abell noticed the development of the participant's self-knowledge about her beliefs and practice. The participant acknowledged the tension between her beliefs and practice and learned to modify her practice as a result. A preservice teacher learned from experience when was placed in a teaching context and encouraged to observe and reflect on her teaching through questions that challenged her to analyze and refine her practice.

Zembal-Saul, Krajcik, and Blumenfeld (2002) conducted a case study that focused on the development of preservice teachers' science content representation. Results showed that with opportunities to write and orally reflect on development of content representation, preservice teachers could maintain a subject matter emphasis. Results suggest that reflective practice is more influential than extensive science background and experience on development of content representation. This finding suggests that reflective practice, a large component of lesson study, could improve PCK.

Nilsson (2008) explored development of PCK during a teacher education program. Four preservice teachers were required to teach Physics lessons once a week for 12 months. One third of the lessons were videotaped, and the videos were used for stimulated recall interviews—a semi-structured interview that facilitated teachers' learning from their experiences and elicited information about their views of their teaching. Two raters independently analyzed the transcriptions of the interviews focusing on subject matter knowledge, pedagogical knowledge and knowledge of context. Results affirmed that teaching experience and reflection facilitate preservice teachers' PCK development. Reflective practice seems to influence PCK development.

Unlike the aforementioned reflective approaches, the lesson study approach applies the reflective practice in a collaborative context with peers. We believed our approach to lesson study may provide even better opportunity for reflective practice, and therefore PCK development, as a result of the realistic setting and feedback from a team of peers and experienced others. Instead of watching and analyzing a video of their own teaching through stimulated recall interviews, a group of preservice teachers meet and debrief weekly about the lessons they teach. Field notes taken during the lesson by peers are used to facilitate the discussion. In addition, the university field instructor and classroom teacher participate in the lesson study discussion.

Marble (2007) used a form of lesson study in an early field experience for science. Marble grouped the preservice teacher participants into teams of three. Each team collaboratively planned an integrated science and mathematics lesson, which was taught in each of their classrooms. Instruction was video recorded and observed with the other two in the team. After each lesson, they debriefed and redesigned the lessons. From analysis of the participants' summary portfolios and the researcher's field notes, it was determined that preservice teachers improved their classroom practice in four aspects, including planning and design; creating a positive learning environment; engaging students; and assessing student learning. As did Marble, we modified Japanese Lesson Study to fit within our preservice elementary field experience context.

Elementary Teachers' NOS Instruction

Although there has been some success in helping science teachers develop their understandings of NOS, it is still challenging to help those science teachers transfer such understanding to their teaching practice. The research on experienced teachers' PCK for teaching NOS revealed that through professional development and collaborative work with NOS teaching experts, teachers were able to develop their knowledge of how to teach NOS and helped their students develop appropriate conceptions of NOS. For example, Akerson and Abd-El-Khalick's (2003) case study of an experienced elementary teacher showed that though she held an informed view of NOS and intended to help her 4th grade students develop their understandings of NOS; these beliefs did not transfer to her classroom practice. She lacked knowledge to teach NOS and needed support to translate her views of NOS and her intention of making the concepts accessible to her students (i.e., PCK for NOS). However, after discussion and observations of lessons modeled by the expert, the teacher incorporated and explicitly taught NOS to her students. This finding shows that although knowledge of and intention to teach NOS are necessary, they are insufficient. Teachers need support in how to integrate NOS explicitly. This finding contributes to the current study as the Lesson Study format seeks to provide such support by having peers as well as knowledgeable others (Yoshida & Jackson, 2011) provide feedback and suggestions for improving the lessons, including how to better include NOS. In another study, Hanuscin, Lee, and Akerson (2011) provided this support in their 3-year professional development program designed to help in-service teachers develop their views of NOS and PCK for NOS. The results indicated that during 3 years of observing and collaborating with experts elementary teachers developed understanding of NOS and instructional practice. They successfully improved their students' understandings of NOS. We believe that the model of lesson study we are able to implement with the structure of our field experience would provide similar support to develop NOS PCK.

Research studies that focus on preservice teachers revealed that, unlike experienced teachers, beginning teachers had more difficulty translating their beliefs about NOS into classroom practice (e.g., Brickhouse, 1990), indicating they had not developed PCK for teaching NOS. Abd-El-Khalick et al. (1998) attempted to identify the factors that mediate the translation of preservice teachers' conceptions of the NOS into classroom practice. Results showed that while an adequate conception of NOS is prerequisite for NOS teaching, such understanding alone is insufficient for teaching successfully. Other factors influenced preservice teachers' instructional decisions and how they enacted their instruction. Researchers found that student teachers rarely addressed NOS in their instruction and did not intend to teach NOS. The results revealed that this outcome was caused by lack of internalization of the value of NOS, preoccupation with classroom management, discomfort with their own understanding of NOS, lack of resources and experiences, cooperating teachers' imposed restraints, and lack of planning time. In our current study, we hoped to overcome this tendency to exclude NOS by using a form of lesson study to enable preservice teachers to reflect on their teaching and receive feedback about teaching NOS from peers and experienced others.

Lederman, Schwartz, Abd-El-Khalick, and Bell (2001) identified four factors influencing preservice teachers' NOS teaching. Those factors include (a) knowledge of NOS, (b) knowledge of subject matter, (c) pedagogical knowledge, and (d) intentions towards teaching NOS. These factors are directly linked to PCK. The intention to teach NOS had more influence on preservice teachers' science instruction. This notion was affirmed by Akerson and Volrich's (2006) study examining the teaching practice of a first-grade teacher intern. This study revealed that knowledge of NOS and the intention to teach it were crucial factors mediating the transformation of teacher's views of NOS into practice. The preservice teacher developed an informed view of and intention to teach NOS from her methods course. During her subsequent teaching internship, she explicitly taught NOS in her first-grade class, emphasizing the distinction between observation and inference, the role of empirical evidence, and the subjective aspect of NOS. Results showed that her instructional strategies influenced the first graders' conceptions of the NOS. Using lesson study we hoped that we could capitalize on this type of feedback preservice teachers would receive that would help them develop PCK for NOS.

PCK for Teaching NOS

The cognitive understanding of subject matter content such as NOS and the relationship between that understanding and classroom instruction is referred as PCK (Shulman, 1986). Therefore, the PCK for NOS refers to the teachers' understandings of NOS and the relationship between such understanding and teaching it. NOS could be viewed as part of the syntactic subject matter knowledge that teachers need to teach and therefore need to develop their PCK for teaching. According to Abd-El-Khalick et al. (1998), PCK for teaching NOS refers to the "knowledge of alternative ways of representing aspects of NOS [that] would enable the teacher to adapt those aspects to the diverse interests and abilities of learners" (p. 692). They recommended that for a teacher to develop PCK for teaching NOS, they need "to comfortably discourse about NOS, design science based activities that [will] help students comprehend those aspects, and contextualize their teaching about NOS with some examples or stories from history of science" (p. 693). Results from several studies revealed that PCK can be developed through teaching experience. Lederman (2007) recommended that for science teacher educators to understand how teachers develop their PCK for NOS, there is a need for studies that adopt a "PCK perspective… as a lens for research on the teaching of NOS" (p. 870).

Hanuscin (2013) conducted a self-study to document a preservice teacher's PCK for NOS in three different phases of a preparation program. The findings supported the notion that development of PCK may vary as a result of variation in developing each knowledge component of PCK (Magnusson et al., 1999). Results showed that knowledge of curriculum and the knowledge of assessment were less developed than other PCK components, which influenced how the preservice teacher emphasized NOS in her lessons. Regarding knowledge of curriculum, the authors discussed that for new teachers, developing a curriculum that emphasizes NOS is a difficult and time-consuming process. To teach NOS, it is crucial for teachers to be able to "establish a classroom environment that reflects the norm and practice of science" (p. 14). To foster the development of PCK for teaching NOS, scaffolding in terms of modeled lessons and activities should be provided. The preservice teachers should be encouraged to revise or develop their NOS emphasis lesson based on the existing materials (Schwartz & Lederman, 2002).

To gain more understanding of PCK for teaching NOS, Hanuscin, Lee, and Akerson (2011) conducted a grounded theory study to document the practice of three experienced elementary teachers. The teachers participated in a 3-year professional development program to develop their PCK for teaching NOS. They were considered effective NOS teachers as they had a clear rationale and commitment to teach NOS and successfully helped their students develop conceptions of NOS. To characterize their PCK for NOS, the researchers reviewed classroom artifacts (e.g., lesson plans, teachers' conference presentations), field notes from classroom observations, stimulated-recall interviews, individual interviews, and a focus-group session conducted with teachers. Modified analytic induction (Bogdan & Biklen, 1998) was used to develop the coding schema for data analysis. The researchers based their evaluations of teachers' NOS teaching practices on four criteria: "that teachers (a) planned to teach a particular aspect of NOS; (b) students were made aware of the target aspect of NOS; (c) students were provided an opportunity to discuss and/ or reflect on their ideas about the target aspect of NOS; and (d) teachers elicited students' ideas about NOS before, during, or at the conclusion of the activity" (p. 9). Findings showed that teachers used the following strategies: (a) translating aspects of NOS into kid-friendly terms; (b) emphasizing NOS in the context of inquiry; and (c) using children's literature to draw analogies to NOS ideas. These criteria were the preliminary coding themes for content analysis of the lesson plans and videos of preservice teachers' instruction in the current study.

Davis and Smithey (2009) explored beginning teachers' strengths and struggles with science teaching. The researchers anticipated three problems of prospective teachers' practice and used these as frames for the goals of their methods course. The goals included teaching inquiry, use of curriculum materials and recognizing students' ideas. The results of the study indicated that although inquiry was valued by beginning teachers, it was not explicitly included or taught. The researchers found that the beginning teachers understood scientific inquiry and intended to teach it, but struggled to transfer their knowledge into practice. The findings revealed the development of initial PCK development, or what they termed as *PCK readiness*, through the experience in science methods class. We find this concept helpful to interpret results of the current study.

Methods

Case study research examines aspects of a setting, subject or contemporary phenomena within real life contexts. We used a case study approach to examine a group of preservice teachers develop their PCK for NOS through reflective practice in lesson study. Creswell (2013) describes case study research as a qualitative approach in which the investigator explores a real-life, contemporary bounded system over time, through detailed, in-depth data collection with multiple sources of information. Case studies can be distinguished by their intent, ours is an instrumental case study because we focused on an issue or concern, and selected one bounded case (a group of six preservice teachers over a five-week period) to illustrate the issue. While some argue that case study is a choice of what is to be studied, we use it as an approach for inquiry, a methodology, or research strategy (Creswell, 2013; Merriam, 2009; Yin, 2009).

These six preservice teachers were enrolled in the same section of a science methods course and early field experience, and taught in the same field experience classroom. We selected this group from the class because each of them agreed to participate in the research study, and we had a complete set of data from the group. They were working as a group, and teaching a unit on scientific modeling, which is particularly amenable to the inclusion of NOS, even by preservice teachers (e.g. Akerson, Donnelly, Riggs, & Eastwood, 2012). They were all in their junior or senior year of their teacher preparation program, and majored in elementary education. They were Caucasian, female, and between the ages of 20 and 22. All preservice teachers had the same content background, having taken college biology, physics, earth science, and as freshman or sophomores completed a course titled *Introduction to Scientific Inquiry.* Within the course on Scientific Inquiry, they received instruction in NOS as a content area. This NOS content was introduced early in the semester and emphasized through the semester in scientific investigations. The six preservice teachers passed the course with high grades (lowest being an A−) and we knew they had at least adequate understandings of NOS, as identified by their responses on the VNOS-B (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) at the end of the *Introduction to Scientific Inquiry* course.

In their elementary science methods course, they learned strategies for teaching NOS to children, such as debriefing science lessons, using children's literature, and ways to embed NOS into science content. As a team, they developed a five-lesson unit to teach a 5th-grade class on the topic of *Models and Designs* (Full Option Science Systems, Lawrence Hall of Science, 2014). They identified the learning objectives and designed each lesson together. Each week two taught a lesson, while the other four observed. Within the teaching pair, one preservice teacher took the role as lead teacher and the other a co-teaching role. One preservice teacher did not lead a lesson, but served the supporting role twice. After each lesson, the team of six engaged in a lesson study session to reflect on what the children learned, provide feedback to peers who lead the lesson, and inform the team what modifications may need to occur in the next planned lesson.

Context: Science Methods Course and Implementation of Lesson Study

The six preservice teachers were concurrently enrolled in their science methods, math methods, and shared early field experience courses. The first half of the semester was focused on teaching mathematics and the second half on teaching science. A similar lesson study protocol was used to reflect on teaching for all math and science lessons.

Building from what they experience in the *Introduction to Scientific Inquiry* course, the first few weeks of the science methods course focused on refreshing the preservice teachers' conceptions of NOS, and on strategies for teaching NOS to elementary students. Preservice teachers reflected from a teacher's perspective on how to teach elementary students about NOS.

The science methods and field experience courses were taught by the same instructor. The methods course included both decontextualized and contextualized NOS instruction (Clough, 2006). All activities were taught using explicit and reflective instruction (Akerson et al., 2000). Decontextualized NOS instruction included the Mystery Samples activity (Ansberry & Morgan, 2005). Contextualized instruction included a variety of activities that embedded NOS into science content conducted at stations (electrical circuit, gravity station, Pluto station, and Alka Seltzer/vinegar/water station). The preservice teachers explored stations and identified the NOS aspects evident in each station. These activities provided examples of NOS instruction that could be used with elementary students. Preservice teachers reflected verbally and in writing, on what NOS they identified in the lessons, and how they could use these kinds of activities with students.

The preservice teachers were placed at an elementary school for 2 h and 40 min each week. In the field they participated in four components including: (a) formative assessment interviews (FAI), during which each pair of preservice teachers interviewed a pair of elementary students from their class; (b) construction of models of children's thinking, during which preservice teachers created a predictive statement that could be used as a model of students' thinking; (c) teaching a lesson; and (d) lesson study, during which preservice teachers discussed the lesson taught. This approach was iterative as they experienced weekly all four components with different members of the teaching team taking the lead on each component.

For this study, we focus on only the teaching and lesson study components of this approach, as these were the two phases in which they implemented and reflected on their NOS instruction. The field experience did not include additional explicit and reflective NOS instruction; but the preservice teachers were consistently asked during their lesson study sessions to identify how NOS could be incorporated into their teaching of science with children.

Similar to the original Japanese Lesson Study (Lewis & Tsuchida, 1998), the preservice teachers met in a team to study the state science education standards, identify the goals of their lessons, and referred to the Full Options Science System (FOSS) (Regents of the University of California, 2011) curriculum series to design their series of five science lessons to meet the selected goals. Throughout this experience they received feedback and guidance from their science methods instructor, who provided suggestions for teaching and assessing NOS.

The implementation of the lessons and the lesson study meeting differed in several ways from the original Japanese Lesson Study model. First, the preservice teachers received feedback from the peers in their team, as well as from two expert observers—the classroom teacher and the university instructor. Second, the Japanese model requires the re-teaching of the revised lesson in a different classroom by one of the participating lesson study teachers, but these preservice teachers implemented each lesson in their mini science unit only once due to time constraints and the nature of only being at the school 1 day a week. However, they discussed in lesson study meetings modifications to the next planned lesson and made changes and revisions to their lesson plans with this feedback. Third, each week one preservice teacher took the role of the lead teacher, but another acted as a support teacher or aide. The other preservice teachers and the two experts assumed the roles of observers. While the lesson was being taught, all observers focused on the elementary students interacting with the materials and took notes on the lesson using a specially designed observation form (see "Appendix" for example). The lesson study meeting occurred immediately following the teaching. All participants (teachers and observers) engaged in lesson study to debrief the lesson and think about modifications to the next lesson.

The discussion began with the lead and support preservice teachers reflecting on how the lesson that day went—what went well and what did not. Then the observers shared their thoughts about the lesson using the information recorded on observation forms. The observers provided specific comments related to students' understandings of key concepts of the lesson and feedback they had for improving the lesson. The final step was discussing revisions for the next lesson. During the lesson study meeting, the university instructor provided feedback on the lesson, and facilitated the lesson study meeting. Feedback was provided regarding embedding NOS into instruction, and assessing students' conceptions of NOS. Following the lesson study meeting and feedback, the lead preservice teacher submitted a lesson reflection and revised lesson plan.

Data Collection

Data sources included (a) videos of the lessons and lesson study sessions; (b) lesson plans and artifacts; (c) revised lesson plans and self-reflection from the lead teacher; and (d) observation forms completed by peer observers during lessons. Peer observers took field notes of student actions, artifacts and conversations; and from the field notes, explained students' understanding of lesson concepts; and provided at least two suggestions for lesson revision. Prior to teaching, preservice teachers submitted a lesson plan. After implementing the lesson and engaging in the lesson study session, the lead preservice teacher submitted a lesson revision and a reflection about teaching and was encouraged to include comments from the lesson study discussion.

Data Analysis

Each data source (initial lesson plans, lesson videos, lesson study session videos, lesson observation forms, revised lessons, and lesson reflections) was analyzed by the first two researchers using NOS coding themes to determine whether and how NOS instruction was planned for and implemented. A frequency count was made of the number of times NOS aspects were included in each data source (e.g., the number of times *tentative NOS* was found in lesson plans, lessons taught, and lesson study feedback sessions). Emergent themes were noted in the data, such as *NOS explicitly taught* or *Consistent feedback being provided regarding NOS instruction during lesson study.* After separately completing analyses, authors met to compare findings. Discrepancies were discussed and data were consulted, until they came to consensus.

We looked in the data for evidence that NOS being included, and that PCK for NOS was being developed, in terms of Hanuscin et al., (2011) criteria for PCK for NOS: (a) preservice teachers planned to teach NOS, (b) students were made aware of NOS ideas, (c) students discussed or reflected on ideas about NOS, (d) preservice teachers elicited students' ideas about NOS. We looked for evidence that the preservice teachers were developing (a) orientations toward teaching NOS, (b) knowledge and beliefs about including NOS, (c) knowledge and beliefs about students' understandings of NOS, (d) knowledge and beliefs about assessment of NOS, and (e) knowledge and beliefs about instructional strategies (Hanuscin, 2013).

Findings

Results indicated some transfer of preservice teachers' knowledge of NOS to their teaching of NOS, and they were developing PCK readiness for teaching NOS (Davis &

Smithey, 2009). They began to discuss some aspects of NOS during the lesson study sessions following lesson two, and some of the discussed aspects were explicitly taught in the subsequent lessons.

Our findings are organized by data source to provide insight into emphasis of NOS over time. See Table 1 for information regarding when NOS aspects were discussed throughout the teaching and lesson study cycle. We describe details of our results in the following sections.

Initial Lesson Plans and Lesson Implementation

This group of six preservice teachers worked together to design the set of five lessons, to provide feedback regarding the lessons, and to revise the lessons using the modified lesson study approach. Therefore, we report the results for the group as they worked as a group. Through the analysis of the preservice teachers' first lesson plan, we sought evidence that they included NOS learning objectives and associated standards, and looked for whether they included activities to teach and assess NOS. However, the preservice teachers did not include NOS learning objectives, nor were activities or assessments for NOS included, despite suggestions from peers and expert observers. This lack of inclusion of NOS in the lesson plan leads us to question whether the team had yet developed an orientation for teaching NOS, despite it being emphasized in their methods course. The objectives of the lesson plan focused on students' understanding of models and designs and their importance. These objectives do have implications for NOS understandings, such as making observations and inferences of empirical evidence to create models, so clearly the preservice teachers were making some NOS connections, but the lesson objectives were not specific to individual NOS aspects that had been discussed in the methods course. For instance, the following objectives were stated in Lesson 1:

Students will be able to

- Observe and interact with different examples of models and designs and determine the important characteristics that models and designs have.
- Describe situations where models and/or designs are helpful and explain the importance of using models and designs in real life.

Table 1 Emphasis of NOS aspects discussed throughout the teaching and reflection cycle by Data Source

Data source	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5
Lesson implementation (video)	–	–	1	1	1
Lesson study (video)	–	1	1	1	1
Written reflections	–	–	–	1	–
Revised lesson plan	–	–	–	–	–
Lesson observation form	–	–	–	–	–

The objectives also focused on the scientific process in terms of *carrying out* science. For instance, in lessons 4 and 5, students were asked to design a bridge (lesson 4) and then construct the bridge (lesson 5). The preservice teachers gave directions to the students on what materials would be available for the activity so they could consider these materials when designing their bridge. While creative NOS could be assumed in the process of designing a safe and useful bridge, the preservice teachers did not explicitly make connections to the creative aspect of NOS in the text of the lesson plan. From our review of the state standards in each lesson, we found the preservice teachers included content and scientific process related standards and did not include standards related specifically to NOS, though NOS may be implicit when the lesson was taught.

From analysis of the videos, there was evidence that the preservice teachers became more explicit about teaching some aspects of NOS toward the end of the science unit, showing that although they did not include NOS in their lesson plans, they were still developing PCK for teaching NOS. For example, in Lesson 3, the preservice teachers discussed how students *acted like scientists*. The preservice teachers emphasized and made connections from the classroom inquiry to aspects of NOS for the students, which may be appropriate as early instruction of NOS:

> Preservice Teacher: How did you act like scientists today?
>
> Student: We collected data and then developed an idea from that.
>
> Preservice Teacher: Can you tell me more?
>
> Student: Well, we had to collect data on what might be in the box (black box activity), and then develop an idea of what was in the box from that data.
>
> Preservice Teacher: Great—that means that like scientists, sometimes you can't directly see something, but with data, you can still make a conclusion.

That preservice teachers were connecting NOS to the science lesson shows students were being made aware of a target aspect of NOS, and were provided with an opportunity to discuss and reflect (Hanuscin et al., 2011). This is an indicator of the development of PCK for NOS, as it provides evidence of understanding instructional strategies for NOS (Hanuscin, 2013).

The aspects of NOS that were most frequently present in lessons and lesson study feedback sessions were empirical based NOS and the distinction between observation and inference. In Lessons 4 and 5 lesson study meetings, preservice teachers discussed how *students were like scientists*, and concluded that it was because *they made observations and inferences, and conducted some testing and experiments which scientists usually do*. It was clear that they were talking about methods of science, not a single method. In fact, one preservice teacher stated:

> It is great that the students are learning many different methods to collect data, and to interpret it too! They aren't stuck thinking there is just one way to do science, but hopefully will get the idea that science is more creative.

This discussion about students' knowledge of science is evidence that they were developing knowledge and beliefs about students' understandings of NOS, showing that they were expanding their PCK for NOS.

Another NOS aspect that was discussed in the lesson study session toward the end of the five lessons was subjectivity. However, preservice teachers only alluded to this aspect of NOS when saying that students had different designs of the bridges because they all have different ideas:

> Facilitator: Why do you think they all had such different designs for their bridges?
>
> Preservice Teacher 1: Well, they all had different ideas, they are different people.
>
> Preservice Teacher 2: Yes, they had different knowledge sets and ideas that they brought to the classroom—they would naturally create different designs. Scientists do the same thing—bring their knowledge to their work—it influences their work.

They did not use the term *subjectivity* in their discussion nor discuss influences different ideas, but they acknowledged that the students' different ideas influenced design of the bridges. This indicates a development of their PCK for teaching NOS because it shows that they were thinking about their students' understanding.

Lesson Observation Forms

Analysis of the weekly lesson observation forms showed that preservice teachers rarely discussed students' ideas related to NOS on the forms and seldom included the emphasis of aspects of NOS in their written suggestions for lesson revision. The aspect on which they most often provided written feedback was observation and inferences.

We sought overall themes through preservice teachers' field notes and suggestions for the lesson revision. The results indicated that the preservice teachers focused on science content and students' ideas about the content early in the unit. Their focus shifted to classroom management and the use of materials toward the end of the unit.

For instance, one preservice teacher suggested the following revisions of Lesson 1:

> … Make inferences about purposes of models from our conversations. NOS. We spent a lot of time in the launch separating out what students already know, I think we should do less in launch and allow more ending explanation from the students themselves in end based off their inquiry stations. [Use] exit slip.

This feedback provided by a preservice teacher illustrates that she had knowledge about instructional strategies for teaching NOS, indicating she was developing PCK for teaching NOS (Hanuscin, 2013). She was making recommendations for spending more time on NOS, and for using the lessons on models for teaching about NOS. When she stated *launch* it was a way they chose to begin the lesson, with collecting ideas students already had about models, leaving less time to discuss the NOS ideas present in the scientific inquiry.

However, the same preservice teacher began to focus on management activities in later lessons, rather than science content or NOS. For example, in her feedback for revising Lesson 4, she wrote the following suggestions:

> The students were encouraged to use labels but could not see the little paper on board with spellings and dimensions. Perhaps this could have gone on the overhead. Also, the students wanted to play more with the materials and car spread out in the room than using them to discuss design. Perhaps keeping them by the window would have been better.

> Finally, for Lesson 5, she discussed the following issues.

> Used cardboard as a material because it can bend as a ramp. Needed guardians as safety so cars would not fall off. Students collaborated on how to make sure materials were taped/glued level so the car would be able to cross safely. Bridge was designed only as a one-way "because of the smaller width."

Therefore, there was a disconnect between the goals for teaching about NOS and actual implementation into classroom practice. It is clear that in this final lesson the preservice teachers were more concerned with processes and management rather than science content or NOS instruction. We believe that preservice teachers were struggling with classroom management and later in the unit gave less thought toward science and NOS content. They were faced with realities of teaching a group of students who were easily distracted, and had issues with organizing materials, both of which could have deterred their focus from the science and NOS content.

Lesson Study Session

Although preservice teachers did not explicitly include aspects of NOS in their original lesson plans, during the lesson study feedback sessions they discussed ways of incorporating NOS aspects into future lessons. From Table 2 it is clear that though no feedback was provided regarding the creative NOS, social and cultural NOS, or the distinction between theory and law, feedback was provided several

Table 2 Frequencies of the emphasis on each aspect of NOS in lesson study sessions

Aspect of NOS	LS1	LS2	LS3	LS4	LS5
Tentative	–	1	–	–	–
Empirical based	–	1	1	–	–
Observation/inference	–	1	2	–	–
Subjective	–	–	–	1	–
Creative	–	–	–	–	–
Social and cultural	–	–	–	–	–
Theory and law	–	–	–	–	–

times regarding the idea that scientific knowledge can change with collection of new data or reinterpretation of existing data, the idea that science knowledge requires empirical data and interpretation data, and the distinction between observation and inference. During lesson study session 4, two preservice teachers provided feedback suggesting incorporating the subjective NOS into future lessons. From viewing the lead preservice teachers, they were aware of ways to include some of the NOS aspects, and provided feedback to their peers regarding NOS instruction, despite that they did not include NOS in their own instruction. For example, one preservice teacher stated in a feedback form "In your lesson you could talk about how scientists collect data—how they cannot make up information, but collect the data and then they have to interpret it." Providing suggestions to others for including NOS into science lessons is evidence of knowledge and beliefs about instructional strategies, indicating that they were developing *PCK readiness* (Davis & Smithey, 2009) for teaching NOS.

Lesson Revision and Individual Reflection

There was evidence of the intention to emphasize NOS in the preservice teachers' lesson reflections toward the end of the unit. This intention to teach NOS later in the unit indicates that the preservice teachers were developing an orientation toward teaching NOS, a component of PCK for NOS, or at least developing experience with teaching NOS. However, time constraints were a barrier for including NOS. In her Lesson 4 reflection, Lauren stated,

> Students in the FAI didn't really show comprehension of the NOS aspects from the unit, so during the Explore section of the lesson, I tried to make a culminating effort to bring back a NOS concept. However, there was short amount of time to do this, so I am unsure of how effective it was.

This comment from Lauren also indicates that she was thinking about students' understandings of NOS and assessing their NOS ideas through the formative assessment interview, and was embedding NOS into her lessons despite the limitations of time that she felt. She embedded NOS in her lesson by including a discussion on the distinction between observation and inference in her lesson on scientific models as a result of conceptualizing her students' NOS ideas. She was exhibiting evidence of PCK for NOS in the realms of orientations toward teaching, knowledge and beliefs about student understandings, knowledge and beliefs about assessment, and knowledge and beliefs about instructional strategies for teaching NOS, by persevering to include NOS in her teaching despite classroom time constraints.

Although the preservice teachers did not make explicit connections to NOS in their initial lesson plans, they became more aware of the value of NOS over time, discussed including NOS in their instruction, and made suggestions for including NOS in subsequent lessons. However, their intention did not always transfer to their practice, and any NOS that was included was not specifically planned. They taught NOS (empirically based; observation and inference; subjectivity) in several lessons. They talked about adding creativity in their lesson in the last lesson study session; however, they did not include this aspect of NOS in their actual teaching.

Discussion

Based on our findings, we conclude that very little explicit NOS instruction was enacted regardless of the fact that explicit discussion about how to include some aspects of NOS in teaching science did occur in three out of the five lesson study sessions (refer to Table 1). Indeed, it is disheartening to note that in two of the five lesson study sessions NOS was not discussed. Peer observers made specific suggestions for NOS instruction, such as stating "you could ask them to observe the black box, and then infer what might be inside the box, and then connect that to NOS even more, by asking them to think about the kinds of evidence they used to make that inference." These suggestions were rarely incorporated into enactments of the lessons. Though there were instances of NOS discussed (observation and inference and subjective NOS) in lessons, the preservice teachers did not explicitly plan to include NOS and therefore, less NOS was explicitly taught than we had envisioned based on their prior NOS learning experiences.

There were twice the number of discussion items about four different aspects of NOS (tentative, observation and inference, empirically based, and subjective) in the lesson study sessions, indicating the preservice teachers' abilities to reflect on their teaching aspects of NOS; in particular the empirical and subjective NOS, and the difference between observation and inference. This result is similar to that of Akerson and Abd-El-Khalick's (2003) finding where an experienced teacher with intentions and objectives for teaching NOS could not enact it in instruction without support.

Toward the end of their field experience, preservice teachers were developing orientations toward NOS teaching, knowledge and beliefs about students' understandings of NOS, knowledge and beliefs about assessment of NOS (through the formative assessment interviews), and knowledge and beliefs about instructional strategies for NOS, as noted in their instruction, and mostly through their feedback to one another regarding teaching NOS. Despite having had a course to teach them NOS content, and being in a methods course that provided them with explicit and reflective instructional strategies for teaching NOS, they did not actually observe appropriate ideas about NOS being explicitly taught to students, and this could be a critical component for supporting the transfer of PCK for NOS to the teaching of NOS (Hanuscin, 2013). They did not observe their peers explicitly teaching NOS, nor did they observe their cooperating teacher incorporating appropriate ideas about NOS.

Discussing NOS and providing feedback about NOS teaching, yet not enacting it is similar to Davis and Smithey's (2009) finding that preservice elementary teachers can productively explore issues of importance related to inquiry, but not carry out satisfactory inquiry lessons. Providing feedback to each other regarding teaching NOS, and yet not teaching NOS themselves indicates a "PCK readiness" for NOS instruction. Thus, they are thinking about NOS, and are making suggestions for others to teach about NOS, but not teaching it themselves. As Davis and Smithey claim, we hope this form of PCK readiness for teaching NOS will result in them teaching NOS when they have more experience and opportunity for explicit reflection on NOS teaching.

Davis and Smithey (2009) note that supporting preservice teachers in developing *instructional moves* that will help make plans a success in the classroom as they work with children could aid in helping preservice teachers move from PCK readiness to developing PCK for teaching NOS. Although we endeavored to support them in translating their NOS content and pedagogy knowledge into classroom practice through lesson study feedback sessions and observation forms, it was evident these strategies encouraged them to verbally reflect on NOS teaching, but little transfer was made to their classroom practice, indicating they stayed in the PCK readiness phase—they have ideas about NOS teaching, but do not yet enact them.

Regardless of whether NOS was embedded in the lessons, we can clearly see that the preservice teachers did conceptualize some NOS aspects in terms of teaching them to children, based upon their feedback provided to peers, indicating a development of the component of PCK of instructional strategies for teaching NOS (Hanuscin, 2013). However, the preservice teachers did not discuss, nor provide feedback regarding the NOS aspects of scientific creativity, the social-cultural influences on science, and the relationship between theory and law. In prior research, we noted that it is developmentally appropriate to begin teaching with more *concrete* NOS ideas that are more tangible, such as observation and inference, moving toward the more abstract ideas, such as socio-cultural NOS (Akerson, Weiland, Pongsanon, & Nargund, 2011). It could be that in this case the preservice teachers were more comfortable with those more concrete ideas themselves, thought that these aspects could more easily be embedded into instruction, or would be more easily attainable by their students. More research needs to be conducted to determine why only certain aspects of NOS were included in the lessons, and lesson study feedback sessions.

Recommendations

We recommend modifying our approach to require the preservice teachers to include explicit NOS learning objectives in each lesson. In this way, we hope they will at least recognize the objectives are there during their teaching, and target them when teaching. We recommend requiring preservice teachers to embed NOS teaching strategies directly into the lesson plans. This embedding of NOS could be questions the teachers write to ask students (e.g., where do you see scientific creativity in this lesson?) or strategies for connecting NOS to the content itself (e.g. scientists use observation and inferences. We will make some observations of how bridges work, and infer the best design for our own models). We recommend requiring preservice teachers to include assessments for NOS objectives. For instance, if their objective for NOS is for their students to be able to describe how scientists change and adapt their ideas based on new evidence, they need to design an assessment to see whether their students are capable of doing so (which could be as simple as asking the students to record in their science notebooks how they changed their ideas about the best design for the bridge based on evidence they collected).

Part of our modified lesson study approach required preservice teachers to revise their lessons based on feedback from their peers during the lesson study sessions and the observation notes they received. We recommend asking those providing feedback to make at least one suggestion regarding NOS instruction, one regarding content instruction, and one regarding classroom management. The preservice teachers could be required to make those revisions based on the suggestions of peers and members of the lesson study team. Perhaps making these recommendations explicitly within the lesson plan that they enacted may contribute to their further thinking on teaching NOS aspects explicitly, rather than simply seeing the kinds of recommendations made, and enable them to better build their PCK for teaching NOS.

It is difficult even for experienced teachers to embed NOS into their teaching (e.g., Akerson & Abd-El-Khalick, 2003) but at least planning for the teaching of NOS will enable the preservice teachers to further develop their curricular and instructional knowledge components of PCK for NOS. Although our findings were inconclusive about the benefits of lesson study for improving preservice teachers' abilities to teach NOS, we found it provided a venue for them to reflect on NOS teaching, as teachers and peer observers, contributed to developing their *PCK readiness* for teaching NOS.

Acknowledgments The research reported in this paper was supported by a DR-K12 grant from the National Science Foundation (NSF), under grant number DRL-0732143. The authors wish to thank all the members of the IMB research team.

Appendix

Observer______________________________**Date**__________________________________

Teacher______________________________ **Lesson** ________________________________

Lesson Observation

*Review the objectives and plans for the lesson. Observe students at a table where at least one of your FAI students is sitting. Record observations, not inferences, in your field notes.

Field Notes

Include anything students say or do that demonstrates their thinking about the topic and concepts. For example, you might include comments and/or questions in group and whole class discussions, engagement with materials, or written work, including drawings.

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