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Abstract: *This study examined a professional development project for K-12 science teachers that engaged participants in an authentic scientific investigation along with explicit-reflective attention to nature of science (NOS). The Views of Nature of Science (VNOS) and Views of Scientific Inquiry (VOSI) Questionnaires (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Schwartz, Lederman, & Thompson, 2001) were used to examine the relationship between teachers' views of NOS and specific aspects of the professional development project. Results of the study show that teachers' views of NOS were influenced by the multidisciplinary, primarily non-experimental research that they engaged in, the opportunity to observe interactions of scientists from different disciplines, and explicit classroom activities and discussions regarding NOS.*

Keywords: nature of science; teacher's views; teacher professional development; math and science education

Introduction

Contemporary reform documents have emphasized the importance of helping students develop adequate conceptions of the nature of science (NOS) (AAAS, 1990, 1993; National Research Council [NRC], 1996). However, research has shown that teachers' understandings about NOS are frequently inconsistent with current conceptions (Abd-El-Khalick & Lederman, 2000;

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Lederman, 1992). If teachers hold naïve views of NOS then they will almost certainly pass these beliefs onto students. Therefore, a necessary step in improving instruction and students' conceptions related to the nature of science involves first addressing teachers' conceptions of NOS.

Engaging teachers in research experiences has shown some success with moving teachers towards more informed views of NOS (Lord & Peard, 1995; Schwartz, Lederman, and Crawford, 2004). A few studies have begun to examine factors that enhance the impact of these research experiences, such as the use of reflective journals and explicit NOS activities (Schwartz, et al., 2004; Richmond & Kurth, 1999). This study builds on this research by specifically examining the characteristics of an authentic research experience that led teachers to re-examine their prior beliefs about NOS.

Theoretical Framework

Definitions of NOS have been debated and have changed over time for philosophers of science and science educators (Abd-El-Khalick & Lederman, 2000). However, there is general agreement about the aspects of NOS that are relevant for teaching K-12 students. Eight aspects of the nature of science – tentativeness, subjectivity, creativity and imagination, observations and inferences, socio-cultural embeddedness, theories and laws, empirical basis, and multiple scientific methods (Lederman, 2004) – provided a focus for the professional development described in this study.

Models of professional development focused on enhancing inservice and preservice teachers understanding of the nature of science have taken many forms, including integration of NOS concepts into methods courses (Akerson, Abd-El-Khalick, & Lederman, 2000; Scharmann, Smith, James, & Jensen, 2005; Tairab, 2002; Ogunniyi, 1983), courses focused on the history and philosophy of science (Abd-El-Khalick, 2005; Akindehin, 1988), and professional development projects involving research experiences with scientists (Schwartz, Lederman, & Crawford, 2004).

Many teachers at the elementary and secondary level have never been directly engaged in scientific research. Their view of science has come primarily from K-12 and university level coursework that often focuses on the concepts and skills of science rather than the nature of the scientific process. Engaging teachers in research with scientists places them within the community of practice of science (Lave & Wegner, 1991). When teachers experience authentic inquiry with scientists they engage in peripheral participation that allows the teachers to speak with the scientists about their activities, identities, artifacts, knowledge and practice. This engages participants in learning "... who is involved; what they do; what everyday life is like; how masters talk, walk, & generally conduct their lives ..." (Lave & Wegner, 1991, p. 95).

Although, few studies have examined the influence of authentic science on students' and teachers' understanding of NOS (Schwartz & Crawford, 2004), benefits of research experiences have been documented for students, preservice teachers, and inservice teachers. Undergraduate students engaged in research experiences gained a better understanding of scientific methods (Kardash, 2000). Research experiences have also been found to increase teachers' content knowledge (Buck, 2003, Dresner & Worley, 2006; Raphael, Tobias, & Greenberg, 1999) and confidence with teaching inquiry science (Westerlund, Garcia, Koke, Taylor, & Mason, 2002).

Studies that have examined the impact of research experiences on teachers' and students' views of NOS have shown mixed results. Some studies have shown positive impacts of research experiences on students' and teachers' views of NOS (Lord & Peard, 1995; Richmond & Kurth, 1999; Schwartz, et al., 2004), while others have shown no effect (Buck, 2003; Bell, Blair, Crawford, & Lederman, 2003). Although participants were engaged in research experiences in all of these studies, the studies which found changes in participants' views of NOS also incorporated strategies for making aspects of the nature of science explicit and engaging participants in reflection on their experiences (Lord & Peard, 1995; Richmond & Kurth, 1999; Schwartz, et al., 2004).

Schwartz and Crawford (2004) suggest that research experiences can be used to teach NOS provided that critical elements are integrated with the experience; (1) explicitly treat NOS as content, (2) facilitate reflection, (3) understand that one does not "do NOS". The research experiences provide an authentic context for reflection that is a necessary, but not a sufficient condition for challenging teachers' views of NOS.

Previous studies suggest that research experiences can improve participants' views of NOS when explicit-reflective attention is paid to NOS (Schwartz & Crawford, 2004). An implicit assumption of this argument is that the research experience provides the necessary context for participants to reflect upon their experiences. However, research experiences can vary widely. Furthermore, aspects of NOS (Lederman, 2004) are based upon a characterization of science as a whole and may not be observable in all research experiences. In order to better understand how research experiences may inform teachers' views of NOS, this study examined the relationship between the nature of the research experiences in a professional development project for teachers and teachers' views of NOS.

Description of the Professional Development Program

The Mammoth Park Project was a professional development project for K-12 science teachers that engaged teachers in an authentic scientific investigation along with explicit-reflective attention to NOS. The project involved collaboration between scientists, science educators, and teachers focused on developing teachers' knowledge of NOS, scientific inquiry (SI), and related science content, as well as supporting teachers to implement interdisciplinary inquiry-based instruction. The project consisted of two-days of introductory workshops in the spring, a two-week summer field session, and three Saturday workshops during the following school year. This study was conducted in the fourth year of the project and focuses on the research experiences and associated activities that occurred during the summer workshop.

The professional development model examined in this study varies from many other research experiences for teachers and students. The participants in this project were engaged in multidisciplinary research, they were engaged in all aspects of the investigation from defining questions to interpreting results, and explicit-reflective attention to NOS was integrated with the research experiences.

Multidisciplinary, Primarily Non-experimental Research

In the Mammoth Park Project scientists from multiple disciplines worked together to investigate the paleoecological history of the Willamette Valley in Oregon. The scientists involved in the project included two paleoecologists, two archaeologists, a geologist, an entomologist, and a physicist. The primary goal of the project was to locate peat deposits at the study sites and to examine the peat for evidence of the climate conditions and presence of organisms present at the time being studied. The two paleoecologists involved in the project specialized in diatom and charcoal analysis. The entomologist assisted with identification of insects in the peat. The geologist specialized in soil identification and analysis of stratigraphy. The archaeologists were present to assist with survey techniques and identification of artifacts if any were found. The nature of the research that most of the scientists were conducting was primarily observational and non-experimental. However, the physicist's research was experimental and involved testing hypotheses about the relationship between magnetometry readings and the location of peat deposits. During the project, the teachers interacted with the entire research team rather than being placed with individual scientists. This context provided a multidisciplinary perspective that included experimental and non-experimental research.

Teachers as Co-investigators

During the Mammoth Park Project, scientists and science educators worked together to engage teachers in the investigations that the scientists were conducting in a way that immersed the teachers in the experience without overwhelming them with content or the procedural aspects of the investigation. Teachers were considered co-investigators along with the scientists and were engaged in all aspects of the investigation including defining questions, designing procedures, collecting data, and interpreting results.

The scientists were engaged in actual research related to their individual research programs. However, for the Mammoth Park Project, the scientists were brought together primarily for the purposes of the professional development project for the inservice teachers. Therefore, the scientists' decisions about the directions of the research could not be purely based on their own professional decisions, but rather included collective engagement with the other scientists, the science educators, and the teachers. In many ways this makes the research more "authentic" for the teachers as they were allowed to experience science as co-investigators with the scientists from the very beginning.

Explicit-Reflective Attention to NOS

The Mammoth Park Project was designed by the scientists and science educators to weave activities about NOS and SI throughout the project. In the spring, teachers attended an introductory classroom workshop that introduced them to the focus of the research and engaged them in activities related to aspects of NOS, including observations, inferences, and models. Thus providing the teacher-participants with a background and glimpse of what would be present during the research they would be involved with in the summer.

During the two-week summer institute, additional activities were chosen to address aspects of NOS and explicitly connect to the paleoecological research. The NOS activities were connected to the scientific field and laboratory activities in a deliberate manner to provide the teachers with a concrete connection between the scientific investigation they experienced and the NOS exercises that they might use in the classroom. Explicit discussions of SI focused on the essential features of classroom inquiry identified in the book "Inquiry and the National Science Education Standards" (National Research Council, 2000). This was addressed in a classroom session during the summer workshop and in informal discussions as teachers and scientists engaged in the paleoecological investigation. For example, the science educators continually encouraged scientists and teachers to examine the nature of the evidence that supported claims they were making. Since the scientists and science educators were integrally involved in all of the project activities they were able to take advantage of "teachable moments" that occurred during teachers engagement in the actual research and help teachers make connections between issues that arose during the research and aspects of NOS.

Methodology

An interpretive case study approach (Merriam, 1998) was utilized to examine the relationship between teachers' views of NOS and their experiences in an authentic research experience. The primary researcher was a participant observer in the professional development. This allowed the researcher to place the teachers' conceptions within the context of the professional development that they were engaged in.

Participants

Twenty-five inservice teachers participated in the Mammoth Park Project during the fourth year of the project. Fourteen of these teachers completed the pre-, mid- and post-questionnaire and were included in this study. There were ten females and four males. The teachers taught grades ranging from 4th through 12th and the length of their teaching experience ranged from 1 to 24 years (Table 1).

Table 1

Background Information for the 14 Participants in this Study

Name	Grade Taught	Subject Area Taught	Years of Teaching Experience
Sarah	4th	All subjects	2
Deborah	4th	All subjects	9
Matt	5th	All subjects	4
Todd	5th	All subjects	13
Kelly	5th	All subjects	17
Heather	5th	All subjects	24
Brenda	7th	Life Science	1
Nancy	7th	Science and Math	23
Allison	8th	Integrated Science	3
Peter	8th	Earth and Physical Science	6
Paul	8th	Integrated Science	10
Lisa	9th	Physical Science	3
Rebecca	10th	Biology	1
Melinda	9th – 12th	Astronomy, Geology, Environmental Science, Biology	20

Note. Names are pseudonyms.

Data Sources

The VNOS-C' and VOSI Questionnaires (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Schwartz, Lederman, & Thompson, 2001) were used to examine teachers views of NOS prior to, during, and following the Mammoth Park Project. The VNOS-C' and the VOSI are open-ended questionnaires. The open-ended nature of the questionnaires provided teachers with the opportunity to explain their views and to connect their explanations to personal experiences, including those from the professional development.

For this study, analysis of the VOSI focused on the aspect of multiple scientific methods and provided supporting evidence for the other seven aspects of NOS. The VOSI questionnaire has questions that address additional aspects of SI, such as the distinction between data and evidence. However, these additional aspects of SI are not addressed in this study.

Teachers completed these questionnaires prior to (pre-survey) and following (post-survey) the summer workshop. In addition, one question from the VNOS-C' and one question from the VOSI were given to the teachers at the end of each day during the summer workshop to examine how the activities of each day were influencing their views. In the following discussion, this is referred to as the mid-survey. This study focuses on data from the mid and post-survey.

Because the teachers had the opportunity to engage with the instrument probes and questions on multiple occasions, before, during, and after the project, the instruments became instructional tools as well as evaluation tools. Previous studies have noted that the act of completing the VNOS survey may result in deeper reflection and clarification of beliefs (Bell et al, 2003; Lederman & O'Malley, 1990). This gave the teachers repeated opportunities to consider how their understanding was influenced by their involvement in the paleoecological research.

Data Analysis

Teachers' responses on the VNOS-C' and VOSI from the mid- and post-surveys were analyzed to identify relationships between the teachers' characterizations of NOS and SI and specific aspects of the professional development. The surveys were examined question by question for each teacher. Statements from the mid- and post-survey that specifically referred to examples from the teachers' experiences during the summer field session were identified. This resulted in 60 statements that explicitly referenced the project. Analysis of these statements consisted of two levels of coding. First, the aspect of NOS or SI to which they referred was identified. Second, an inductive analysis was used to identify the aspects of the project that were referenced. Codes related to the aspects of the project emerged from the data. For example, the following response to the question, "What types of activities do scientists do to learn about the natural world?" was coded as "Scientific Methods" and "Non-experimental Inquiry":

> Make observations. Study test samples and collections. Make comparisons to known samples or comparative studies – Ex. We talked a lot about seeing if other soils in valley match the river, etc. Use of maps: elevation, contours, locations, topography, lab work/tests on samples. -> Ask questions and provide evidence to explain. (Peter, VOSI#1, Mid-survey)

The coded statements were then examined and three themes were identified that related to the relationship between the aspects of NOS and the teachers references to the project.

Findings

Analysis of teachers' references to the project resulted in the identification of three themes related to relationships between aspects of NOS and specific components of the professional development model.

Non-experimental, Multidisciplinary Inquiry – Multiple Scientific Methods

The primarily non-experimental nature of the investigation provided teachers with examples of scientific methods that were very different from the experimental methods that many of them were familiar with. Furthermore, the multidisciplinary nature of the investigation provided teachers with examples of various scientific methods that allowed them to compare and contrast the differing methods. As one teacher stated, "The work on the Mammoth Park Project was an example of different scientists with different points of view and different methods, investigating a paleontology dig" (Todd, VOSI #5, Post-survey). Another teacher explicitly pointed out how the research that he experienced during the Mammoth Park Project did not follow the traditional scientific method often illustrated in textbooks. He stated that "Mammoth Park has not been the public educational model of science: state the problem, hypothesis, experiment, collect data, conclusion, etc. We have been a part of multiple problems being identified by various scientists" (Matt, VOSI#5, Mid-survey).

Teachers referred to examples from the Mammoth Park Project to describe how science includes observational methods and experimental methods. One teacher described how the observational nature of the Mammoth Park Project differed from his dominant view of science:

> So far we haven't tested any hypothesis that I know of – and this has been my dominant view of science: form a question, make a hypothesis, and perform experiments/tests that will attempt to answer the question. ... The digging we're planning on performing on Thursday forward seems to be more data collection in an attempt to make sense of the observations. I've witnessed very few hypotheses being entertained so I'm curious to see if this happens (Matt, VNOS #1, Mid-survey).

This response was collected from the participant following the first day of the project. Later in the week, teachers had the opportunity to interact with the physicist on the project who had developed specific hypotheses that were guiding his investigations. This is discussed in more detail below.

Another teacher, who described the things that scientists do as basically following the scientific method in her pre-survey, used specific examples from Mammoth Park in her mid-survey to provide a much richer description of the activities of scientists. She stated that:

> They physically go to the site in question. They will take samples of what they are studying: core samples, plant samples, insect samples, soil samples. They will consult past and present studies of the site. They will research any collected data of the site (Melinda, VOSI#1, Mid-Survey).

The multidisciplinary nature of the investigation also provided an opportunity for teachers to see scientists using various methods in their approaches to the research questions. The paleoecologists, geologists, and archaeologists used primarily observational methods that were not always guided by a priori hypotheses. On the other hand, the physicist had a specific hypothesis about the relationship between magnetometry readings and the location of peat deposits. One teacher used this contrast between the types of research to describe how science does not follow one scientific method:

> At Mammoth Park Project this past summer, I saw this actually play out. As we began our process, [the geophysicist], announced his hypothesis for his portion of the project. The data that we would eventually collect would support or not support his hypothesis. While talking to the other scientists on the project, they were waiting to see what the data showed prior to setting a hypothesis. Both are scientific because the data was collected systematically and both will still lead to conclusions/explanations based upon the evidence/data gathered in the project (Peter, VOSI #5, Post-survey).

Interactions of Scientists from Different Disciplines – Subjective and Socio-cultural NOS

The multidisciplinary nature of the Mammoth Park Project allowed teachers to see how scientists from different disciplines approached questions, designed investigations, and interpreted information. Teachers' references to the Project cited multiple examples of how the interactions of the different scientists were representative of the subjective NOS and the socio-cultural embedded-ness of science.

When asked whether or not scientists could reach different conclusions when asking the same question or interpreting the same data (VOSI #6, VOSI #7, and VNOS #7) six teachers described specific examples from the Mammoth Park Project that were representative of how the different backgrounds and motivations of scientists could influence their interpretations of data. For example, one teacher stated "The same way that [the Archaeologist's] explanation of the gravel deposits at the river level of [location] differed from [the Geologist's] explanation. The data/evidence was the same but their experiences differed enough to influence their view of that evidence" (Matt, VNOS #7, Post-survey).

The interactions of the scientists gave the teachers the opportunity to see how different backgrounds and perspectives can lead to different conclusions. The interactions also gave the teachers the opportunity to see how communication among scientists allowed them to discuss their differing conclusions and the evidence that they used to develop their conclusions. In some cases, they were also able to observe how discussion among the scientists allowed them to reach consensus about how the evidence fit the conclusions. One teacher described an incident where scientists and teachers discovered an unknown white layer in a trench that was dug on one of the sites. Lisa described how she observed two of the scientists come to different conclusions after observing the white layer and how they eventually reached a consensus after discussing their reasoning, "[Archaeologist #2] explained why he concluded it was an ash deposit. [Archaeologist #1] reconsidered and agreed that it was most likely an ash deposit. In other situations, scientists might still draw different conclusions" (Lisa, VOSI #6, Post-survey).

When discussing socio-cultural influences on science, teachers focused primarily on issues of social influences including how scientists choose what to study, comparisons between different scientists, or comparisons between different disciplines of science. When asked about how scientists choose what to study, Matt used specific examples from discussions with the scientists and science educators on the project to describe a variety of factors:

> Factors that I've heard from the scientists on the project: 1. Funding sources – [physicist's] use of the magnetometer influenced by simply having the instrument available via grant. 2. Opportunities available because parents exposed the scientist to specific types of science ([science educator] and her grandfather's influence). 3. Demands of the organization. If a department says do this and the scientist wants to remain in the organization, then they do the study. 4. Personal interest of the scientists ([archaeologist] chose not to study pollen because it wasn't of personal interest to him) (Matt, VOSI#2, Mid-survey).

Teachers also focused on how the different perspectives of individual scientists can reflect social values. Kelly stated that, "Science reflects social and cultural values. Different individuals reflect different social values and interests. Example: the scientists working at Mammoth Park Project…" (VNOS#10, Mid-survey). Deborah specifically highlighted the difference between different scientific disciplines. On her mid-survey she stated "… the culture of physicists is different from the culture of archaeologists" (VNOS#10).

Teachers' references to cultural influences on science focused on discussions they had with scientists and science educators during the project, rather than direct observations of how cultural differences could influence science. For example, on her mid-survey, Allison stated that her view on the influence of social and cultural factors was changing and that this was primarily due to explicit discussions with one of the science educators:

> OK, so I changed my answer on this one. I'm starting to see that science reflects social and cultural values, but that's in a large part due to [science educators'] explicitly saying that today. I did see some of the social aspect in the issues that came up … in regards to scientists being on different pages with their thinking. But, I still don't really have a picture of the cultural aspect since we didn't really do anything with that. (VNOS#10)

One of the teachers explicitly described a story that the science educator told about an event that occurred in Russia. In response to VNOS #10, which asks whether or not science reflects social and cultural values, she stated that:

> Scientists' social, political, and religious selves are a part of their science. An example is the story [the science educator] told of the scientists who were sent to Siberia in Russia because their crop outcome was not desirable. That fear created would have a huge impact on other scientists – and their methods and outcomes (Sarah, VNOS #10, Mid-survey).

A number of teachers also explicitly referenced differences between Western science and Native American science when describing the influence of socio-cultural factors. One of the scientists on the Project had done extensive work with local communities in Alaska and shared multiple examples of differences between Western ways of knowing and Native American ways of knowing.

The multidisciplinary nature of the project provided teachers with experiences in which they could observe how the different individual and disciplinary backgrounds of the scientists influenced their approaches to problems, their methodologies, and their interpretations. This was one more aspect of their exposure to the complexities of NOS.

Explicit NOS Activities – Theories and Laws & Tentative NOS

Teachers' responses specifically referred to NOS activities that were integrated throughout the two-week summer workshop. References to the explicit NOS activities related primarily to descriptions of the differences between theories and laws.

During one of the classroom sessions, teachers were engaged in a discussion of common misconceptions about the nature of theories and laws. Specifically, teachers were asked to reexamine the commonly held view of a hierarchical nature of theories and laws. This view holds that as more and more evidence is gathered, hypotheses develop into theories and theories develop into laws. Alternatively, teachers were exposed to the idea that theories and laws are actually two different, but equally valid types of knowledge. Specifically, it was discussed that laws describe the relationships among observable phenomena, while theories explain the observable phenomena. Furthermore, theories can support laws by providing possible explanations for the observed phenomena that the laws describe, but theories do not become laws.

A number of the teachers' responses to the VNOS question about theories and laws explicitly referenced the definition of theories and laws that was discussed in the classroom sessions. For example, on his post-survey Matt stated that "According to [a science educator] there is a difference -> Laws state, identify and/or describe the relationships among observable phenomena. Theories are inferences that explain the observable phenomena…" (VNOS #5, Post-survey). Another teacher clearly described how his view had changed due to the new information that had been shared with them:

> I used to believe that a theory developed into a law, but now, with new knowledge, I (and many others) am led to believe that there is an inherent difference. I used to say if a theory was beyond any known refute, then it could develop into a law. Now, as I understand it, they are based on two different corresponding details (Paul, VNOS #5, Post-survey).

However, for some teachers, their understanding of the nature of theories and laws showed inconsistencies. A number of teachers expressed an understanding that theories and laws were different types of knowledge while still holding a naïve conception that laws are proven or that theories become laws. These teachers seemed to be restating what they had been told about the nature of theories and laws without fully conceptualizing the distinction. For example, Peter stated on his post-survey, "A theory is not yet accepted as truth, but is still being challenged. Scientific law is accepted as truth. It has been time tested over and over" (VNOS#5). He went on to provide examples of how the theory of plate tectonics is still being challenged and modified, but the laws of motion are accepted as a fact. Then at the end of his response, he identified the following as the "Mammoth Park Project Description: …Law – describes a relationship among observable phenomena. Theory – inferred explanation for observable phenomena". Peter had apparently learned this distinction through his participation in the project, but he had not fully incorporated it into his understanding of theories and laws, nor had it influenced his more naïve view that laws have been proven true and theories are still being challenged.

The teachers appeared to be able to recall the definitions that were discussed during the classroom session, but had trouble integrating these definitions with their former conceptions of a hierarchical nature of theories and laws. For example, on her post-survey, Deborah referred to the definitions that she learned, but then appeared to revert to a hierarchical description of theories and laws when she was unable to refer directly to her journal notes:

> Yes, there is a difference between a scientific theory and a scientific law. If I had my handy dandy journal I could give you an example of each. However, since I've turned it in, I can't remember exactly. …A law can be reproduced and will always be reproduced and will always have the same outcome – it can be proven with the evidence. A theory may not be reproducible. It may not have the same outcome each time (VNOS#5, Post-survey).

These results suggest that for a number of teachers, explicit discussions of aspects of NOS during the Mammoth Park Project made them more aware of the distinction between theories and laws. However, these explicit discussions did not necessarily move teachers toward fully informed views of this aspect of NOS.

Discussion

Research experiences can provide teachers an opportunity to learn more about the practices of science and the nature of the scientific process. Through these experiences scientists often mentor teachers about scientific practices (i.e. methods of data collection and interpretation). However, the aspects of NOS are often more implicit and may not be observed or recognized unless the appropriate experiences and reflective context are provided as a component of the teachers experiences. This study found that the multidisciplinary and primarily non-experimental nature of the research experiences and the explicit-reflective attention to NOS provided a context that challenged teachers' views of NOS.

During the project, the teachers worked with scientists from various disciplines who utilized different methods in their approaches to investigating their particular research questions. The observational nature of the investigations that occurred during the Mammoth Park Project challenged many of the teachers' views of what counts as "science". Involvement in the research gave them specific examples of scientific investigations that differed from their view of the "scientific method" and the single variable experiments with which they were familiar.

Teachers' views of the subjective and socio-cultural NOS were also enhanced by the multidisciplinary nature of the Mammoth Park Project which provided them with the opportunity to observe interactions among scientists from different disciplines. Teachers observed scientists reach different conclusions when examining the same evidence due to differences in their previous knowledge and perspectives. Their interactions with scientists in this project also allowed teachers to directly observe the role that communication among scientists plays in formulating and negotiating conclusions from data. A similar study which engaged teachers in research experiences with scientists conducted by Schwartz, Westerlund, Koke, Garcia, & Taylor, (2003) found that the teachers changed little in regards to their views about subjectivity and socio-cultural aspects of NOS. Schwartz et al. (2003) found that teachers moved from seeing science as culture-free to acknowledging the role of funding on *what* science is done. However, teachers did not recognize the role of culture on *how* science is done. The multidisciplinary nature of this project provided a context that gave teachers direct experience with the role of different scientific cultures (i.e. scientific disciplines) on how science is done and engaged them in informal discussions about how research can differ across cultures.

Changes in teachers' views of theories and laws appeared to be influenced primarily by specific discussions during the workshop rather than experiences arising from involvement in the paleoecological investigation. However, these discussions did not appear sufficient to create conceptual change related to this concept among many of the teachers. Most of the teachers attempted to add the view that theories and laws are different types of knowledge to their prior conception that theories become laws. Although the teachers were told that theories do not become laws, it appears that merely presenting this information was not enough to challenge the strongly held belief in a hierarchical relationship between theories and laws. Dagher, Brickhouse, Shipman, & Letts (2004) showed that even extended instruction at the undergraduate level related to scientific theories often fails to change students' hierarchical views of the relationship between theories and laws. The information presented in this project apparently failed to create the necessary dissatisfaction with the prior belief that would be needed in order to encourage replacement with a more informed view. Instead, teachers attempted to assimilate the new information in conjunction with their prior conceptions. Schwartz et al. (2003) also found that teachers in their project moved towards an understanding of theories and laws as different while still holding a hierarchical view of their relationship.

In this project, the teachers were engaged as co-investigators along with the scientists in an authentic science experience. Teachers were placed in a position where they were directly involved in the research process and had the opportunity to interact with and observe the other scientists as the research progressed. The scientists were forced to make their process more explicit to the teachers in order to truly engage them in the research experience. The scientists did more than just train the teachers to collect data, they openly discussed each step in the research in order to engage and involve the teachers in the decision making process. This made aspects of the processes that the scientists used, including the multiple scientific methods and subjective nature of the scientists interpretations of data, apparent to the teachers.

The explicit-reflective attention to NOS was embedded throughout the project in formal and informal ways. The classroom activities that explicitly addressed aspects of NOS were most directly apparent to the teachers. A number of informal conversations related to NOS also occurred between teachers, scientists, and science educators. The teachers' references to the socio-cultural aspect of NOS often referenced these informal discussions. In most projects involving research experiences the scientists are not directly involved in aspects of the professional development that occurs outside of the scientists laboratory. In this project, scientists were involved in all aspects of the project including the classroom sessions focused on NOS and other pedagogical issues. This allowed the scientists to integrate discussions of NOS and SI into the actual research experience when opportunities arose.

Conclusion

Professional development experiences that aim to enhance teachers' views of NOS need to consider both the specific context of the research experiences that teachers engage with and the nature of opportunities for explicit-reflective attention to NOS. Research experiences that engage teachers in non-experimental and multidisciplinary inquiry can provide a critical contrast to traditional representations of "the scientific method". Engaging in scientific inquiry with scientists from different disciplines can also provide opportunities for teachers to directly observe aspects of the subjective and socio-cultural nature of science. Furthermore, embedding explicit-reflective attention to NOS throughout such a project will support teachers in critically assessing their understanding of the nature of science and its relationship to the scientific research they are experiencing.

References

Abd-El-Khalick, F. (2005). Developing deeper understandings of nature of science: The impact of a philosophy of science course on preservice science teachers' views and instructional planning. *International Journal of Science Education, 27*(1), 15-42.

Abd-El-Khalick, F. & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science Education*, *22*(7), 665-701

Akerson, V. L., Abd-El-Khalick, F., Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching, 37*, 295-317.

Akindehin, F. (1988). Effect of an instructional package on preservice science teachers' understanding of the nature of science and acquisition of science-related attitudes. *Science Education, 72*, 73-82.

American Association for the Advancement of Science. (1990). *Science for all Americans*. New York: Oxford University Press.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy: A Project 2061 report*. New York: Oxford University Press.

Bell, R. L., Blair, L., Crawford, B., & Lederman, N. (2003). "Just do it." The impact of a science apprenticeship program on high school students' understandings of the nature of science and scientific inquiry. *Journal of Research in Science Teaching, 40*(5), 487-509.

Buck, P. (2003). Authentic research experiences for Nevada high school teachers and students. *Journal of Geoscience Education, 51*(1), 48-53.

Dagher, Z. R., Brickhouse, N. W., Shipman, H., & Letts, W. J. (2004). How some college students represent their understandings of the nature of scientific theories. *International Journal of Science Education, 26*(6), 735-755.

Dresner, M. & Worley, E. (2006). Teacher research experiences, partnerships with scientists, and teacher networks sustaining factors from professional development. *Journal of Science Teacher Education, 17*(1), 1-14.

Kardash, C. M. (2000). Evaluation of an undergraduate research experience: Perceptions of undergraduate interns and their faculty mentors. *Journal of Educational Psychology, 92*, 191-201.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: a review of the research. *Journal of Research in Science Teaching, 29*, 331-359.

Lederman, N. G. (2004). Syntax of nature of science within inquiry and science instruction. In L.B. Flick & N.G. Lederman (Eds.), *Scientific Inquiry and Nature of Science* (pp. 301-317). Dordrecht, The Netherlands: Kluwer.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire (VNOS): Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497-521.

Lederman, N. G., & O'Malley, M. (1990). Students' perceptions of tentativeness in science: development, use, and sources of change. *Science Education, 74*(2), 225- 239.

Lord, T. R. & Peard, T. L. (1995). Scientist-teacher summer workshops can enhance constructivist views about science and science instruction. *Education, 115*(3), 445-447.

Merriam, S. B. (1998). *Qualitative research and case study applications in education.* San Francisco: Jossey-Bass.

National Research Council. (1996). *National Science Education Standards*. Washington, DC: National Academy Press.

National Research Council. (2000). *Inquiry and the National Science Education Standards*. Washington, DC: National Academy Press.

Ogunniyi, M. B. (1983). Relative Effects of a History/Philosophy of Science Course on Student Teachers' Performance on Two Models of Science. *Research in Science and Technological Education, 1*(2), 193-199.

Raphael, J., Tobias, S., Greenberg, R. (1999). Research experience as a component of science and mathematics teacher preparation. *Journal of Science Teacher Education, 10*(2), 147-158.

Richmond, G., & Kurth, L. A. (1999). Moving from outside to inside: High school students' use of apprenticeship as vehicles for entering the culture and practice of science. *Journal of Research in Science Teaching, 36*, 677-697.

Scharmann, L. C., Smith, M. U., James, M. C., & Jensen, M. (2005). Explicit reflective nature of science instruction: Evolution, intelligent design, and umbrellaology. *Journal of Science Teacher Education, 16*, 27-41.

Schwartz, R. S., & Crawford, B. A. (2004). Authentic scientific inquiry as context for teaching nature of science. In L.B. Flick and N.G. Lederman (Eds.), *Scientific Inquiry and Nature of Science* (pp. 318-355). Dordrecht, The Netherlands: Kluwer.

Schwartz, R. S., Lederman, N. G., & Crawford, B. A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education, 88*(4), 610-645.

Schwartz, R. S., Lederman, N. G., & Thompson, T. (2001, March). *Grade nine students' views of nature of science and scientific inquiry: The effects of an inquiry-enthusiast's approach to teaching science as inquiry*. Paper presented at the meeting of the National Association of Research in Science Teaching, St. Louis, MO.

Schwartz, R. S., Westerlund, J., Koke, J., Garcia, D., & Taylor, T. (2003, March). Explicit/reflective NOS instruction and authentic science research: Effects on teachers' NOS views. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Philadelphia, PA.

Tairab, H. H. (2002). Pre-service teachers' views of the nature of science and technology before and after a science teaching methods course. *Research in Education, 65*, 81-87.

Westerlund, J. F., Garcia, D. M., Koke, J. R., Taylor, T. A., & Mason, D. S. (2002). Summer scientific research for teachers: The experience and its effect. *Journal of Science Teacher Education, 13*(1), 63-83.