Developing Inservice Teachers' Views of Nature of Science and Inquiry: Immersion in Authentic and Relevant Paleontological Research

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This paper reports the influence of a professional development project on inservice teachers' knowledge and views of nature of science (NOS) and inquiry. The research centered on the second year of a two-year project designed to influence teachers' views by immersion in an authentic research setting. The project also used innovative curricular materials centered in inquiry, NOS, and evolutionary concepts. The theoretical framework included the constructs of situated cognition and social constructivism. We used a mixed methods approach and multiple data sources, (videotaped fieldwork, teacher presentations, written reflections, and interviews). We built on findings from our previous research, investigating the impact of geological fieldwork related to an authentic paleontological study on views of NOS and inquiry of 15 5th-9th-grade teachers. In the first year these teachers learned how to examine real fossils in the field and relevant content in biological evolution, geology, inquiry, and NOS. The current study pushed these same teachers to formulate their own scientific questions and hypotheses. Teachers engaged in hypothesis testing, data analysis and developing explanations, all hallmarks of science. Their experiences, combined with reflection, appeared to enhance teachers' views of NOS and inquiry. The authenticity and relevancy of the fossil investigation, and their own intellectual investment, contributed to teachers' developing understandings of many of the tenets of NOS and inquiry.

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The purpose of the study was to determine the influence of a professional development program focused on teachers' understandings of what it means to teach science as inquiry. We endeavored to develop a chain of evidence of what contributed to teacher change in understanding aspects of nature of science (NOS) and inquiry in the context of an authentic scientific investigation. The project involved teachers from a range of classrooms across the United States, who taught science to children in 5^{th} – 9^{th} grades in public and private schools. The teachers had varied teaching experiences, and many had little or no previous formal coursework in geology or evolution and limited experience in teaching about NOS. The teachers were involved in their second year of a National Science Foundation (NSF) funded project, Fossil Finders: Using Fossils to Teach about Evolution, Inquiry, and Nature of Science. We explored the following question: *In what ways do authentic science experiences and explicit connections to NOS and inquiry influence teacher understandings?*

Related to reform-based pedagogy, most teachers do not routinely use inquiry-based instruction in their classrooms due to a number of issues, including time constraints, lack of experience, and others (Deboer, 2004; Krajcik, Mamlok, Hug, & 2000), or they simply do not understand what inquiry is (Anderson, 2002; Capps & Crawford, 2011). As stated by Borko (2004), "Despite recognition of its importance, the professional development currently available to teachers is woefully inadequate" (p. 3). Education researchers acknowledge that not only do students, but teachers themselves need support in learning about NOS and the fundamental science concepts related to evolutionary theory. Understanding evolutionary theory is intimately tied to NOS and the nature of scientific inquiry. Understanding how paleontologists use observational data as evidence to make inferences about past environments, and understanding the role of scientific theory, are both necessary in constructing an understanding of evolution.

The problem addressed in this study is that many teachers have naïve or limited views of NOS and inquiry (Lederman, 1992). This issue is important to address, particularly in the case of teaching concepts related to evolutionary theory (Kampouraskis & McComas, 2010). One difficulty of teaching the theory of evolution by natural selection stems from misconceptions about scientific theories and laws, and the mistaken notion that theories, when they become more and more robust, eventually turn into laws (Duschl, 1990). That particular misconception allows non-scientifically informed thinkers to assign scientific theories a good deal less respect than does the scientific community. Understanding the difference between scientific laws and theories is absolutely necessary in appreciating the importance of Darwinian theory of evolution by natural selection.

Other aspects of NOS are also important to teach, including distinguishing between observations and inferences. It is critical that teachers help students gain clear insights into aspects of NOS to support understanding foundational concepts of evolutionary theory (Sharmann, Smith, James, & Jensen, 2005). Our study addresses the situation that in many cases, teachers hold positivistic views of science (Pomeroy, 1993), and many believe in a universal stepwise procedure, "The" Scientific Method for doing science, thus discounting the aspects of creativity and imagination in doing science (Abd-El-Khalick & BouJaoude, 1997). Expecting teachers to successfully carry out inquiry-based instruction in their classrooms hinges on their having well informed views of science likely gained from their personal inquiry experiences.

Theoretical Framework

A consideration of how people *learn* science should be at the heart of every educator's decision of how best to *teach* science. A constructivist view of learning positions a person at the center of the experience, as he or she actively makes sense of the environment and builds on previous experiences. This view of learning advocates the kinds of authentic settings that facilitate people in developing in-depth understandings and critical thinking. Learning involves active intellectual participation by the learner, and it includes social and reflective components, as described by cognitive psychologists (Brown, 1994). The main idea is that a learner takes an active role in the learning process, in conjunction with social interaction with others (Vygotsky, 1978). Active learning is associated with meaningful activities, and this view is embodied in the constructs of situated cognition and cognitive apprenticeships.

Nature of science as defined by many science educators involves science as one way of knowing about the world and the system and values of beliefs within which scientific knowledge is constructed and validated (Abd-El- Khalick, Lederman, & Bell, 1998). Some researchers may view scientists' laboratories as the most authentic of all settings for helping teachers learn about the ways in which science is conducted. There is the assumption that an apprenticeship in a science laboratory will directly translate into a greater understanding of aspects of NOS leading to scientific literacy. This assumption is not fully supported by empirical studies (Bell, Blair, Crawford, & Lederman, 2003; Ritchie & Rigano, 1996; Schwartz et al., 2004). For example, findings from the Bell et al. (2003) study clearly showed that most of the high school participants, with one exception, did not change their views of NOS; even though they spent an entire summer working in scientists' laboratories.

Over the past several years our research team has tried different ways to use *immersion in authentic research* as a context for inquiry and engaging teachers in learning about NOS. The theoretical framework that underpins our teacher professional development design includes the constructs of *authenticity* and *reflection.* There are varied views of authenticity in the literature (e.g. Crawford, 2000; Chinn & Maholtra, 2002; Roth, 1995; Woolnough, 2000). Authenticity connects with the time, place, and situation associated with the learning experience (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991). Chinn & Malholtra (2002) highlight the epistemological and reasoning aspects of scientific inquiry. Combining inquiry-based teaching that is situated in authentic science with explicit attention to NOS (e.g. Crawford & Schwartz, 2005) is the pedagogical framework we emphasized in the project reported here. We hypothesized that if we immersed teachers as learners in authentic inquiry research-based experiences ,and modeled inquiry-based approaches which included explicit attention to aspects of NOS, and allowed teachers time to reflect on these experiences, then teachers knowledge of NOS and scientific inquiry would likely be enhanced in a way that would better situate teachers to use science inquiry to teach their students tenets of NOS and evolutionary concepts.

Method

The Nature of the Authentic Scientific Study and the Classroom Investigation

The context of the project was an authentic paleontological investigation conducted in central New York State, U.S.A. Scientists identified the scientific study of Devonian fossils as interesting and important to paleontologists, and it is the kind of research that often requires substantial amounts of basic data – identification of taxa, measurement, characteristics of the enclosing rocks, specimen density, and other parameters. As characterized by paleontologists, researchers are interested in the biological response of a Devonian Period (about 380 million year old) marine community to a sea level drop; implications relate to how marine communities responded to numerous sea level variations occurring in the Devonian and throughout geologic time. Fossil data were collected, as part of the investigation, from a 30 m thick section exposed along a rock outcrop near Pompey, NY.

This scientific research is also the kind that can be done by nonexperts with a modest amount of training (personal communication, Robert Ross, Jan. 3, 2010). From a scientist's perspective the amount of research that can be carried out for a particular research project is often limited by the extent of available human resources. Thus, beyond pedagogical interests, participating scientists are interested in a partnership with classrooms for the enhanced capacity it will bring to collect and analyze data on fossils that might otherwise not be practical. The selected field site is very fossiliferous (rich in fossils), with fossils in rock that can be collected in bulk, and that contain fossils readily identifiable and measurable with basic tools, such as a hand lens and caliper. We have found these aspects to be important for active participation by students in classrooms.

The scientific question as posed by scientists is: How did sea life respond to changes in the environment during the Devonian Period in central New York? The paleontologists on the team identified this question as authentic, and one that other scientists would be interested in studying. The science educators recognized the question as one connected to important science content and could be assessable to classroom students. The rock samples are shipped to classrooms for students to study. Students find fossils in the shale and limestone samples, identify taxa, take measurements and other data such as fragmentation and color, and input data in the on-line project database (see Figure 1 for database screenshot of the website www.fossilfinders.org). Students then analyze and interpret the results of the growing database using graphs and other data displays, with the support of their teachers. In this way there is opportunity for teachers to scaffold students in developing critical thinking skills, as students use data as evidence in developing explanations of scientific phenomena, a central aspect of inquiry-based teaching. As students use data as evidence in developing explanations of scientific phenomena there is opportunity for teachers to scaffold students in developing critical thinking skills, a central aspect of inquiry-based teaching.

To support teachers in carrying out this authentic investigation in their classrooms, we designed a two-year professional development (PD) experience. We selected a group of practicing elementary and middle level teachers. The framework of our designed PD involved four features: a) an authentic scientific question conducive to translation to a science classroom; b) modeling an inquiry approach; c) making explicit connections to aspects of NOS; and, d) inquiry-rich curricular materials. Back in their classrooms, teachers engaged their own students in the investigation of the fossil samples, along with inquiry-designed lessons targeting NOS and geological concepts. The main PD experience involved a six-day summer institute during each of two consecutive summers.

YR 1 Summer Institute Experiences

In YR 1 the summer resident institute featured a packed agenda including four field trips to different rock sites in central New York; discussions in the Geology classrooms of how to find and measure fossils, how to teach about NOS, and use of inquiry-based approaches (led by the science educators); a tour of the Museum of the Earth, that was highlighted by a behind-the-scenes look at the work of paleontologists and the world class fossil collections of the Paleontological Research Institution; evening discussions of ELL strategies (led by the science educators); sessions focusing on specific science content (e.g. evolution and geology), and finally, a lively teacher and scientist discussion of how to deal with controversial issues of teaching about evolution (led by both science educators and scientists). We also held sessions during which scientists shared something about the nature of their scientific research -- what they do and how they go about it from a scientific perspective. We designed Fossil Finders background lessons, or the lessons leading up to the actual investigation, to give experience with the science concepts and process skills they would use during the investigation and analysis. Professional development instructors modeled each background lesson for the participants during the summer institute. Teachers participated in the lessons from the perspective of learners. Explanations were offered: often times rocks are in layers and paleontologists study these layers to learn about the past. Questions were posed: Why might a paleontologist be interested in collecting rocks at many layers throughout a rock outcrop instead of just one layer?

The scientist led field trips focused on learning geological principles and collecting and identifying fossils. Central New York has thick sequences of fossil-bearing sedimentary rocks deposited in a shallow sea that covered the area in the Devonian Period (about 380 million years ago). While in the field, teachers observed the rocks and fossils and were guided by scientists in making inferences about how the history of the site and how the different sites related to one another. Teachers helped collect the research samples that their students would use in the coming school year for data collection and analysis. The samples were taken from specific layers of a particular locality as part of the research being carried out with the partnering paleontologists. The scientific research is focused upon how marine organisms changed in response to environmental changes; for example, changes in sea level and associated changes in sediments, water energy, and available nutrients. Participants collected rock and fossil samples from each site that would serve as reference sets and teaching samples for their classrooms. During the school year teachers used their knowledge gained in the Year 1 institute to carry out the lessons and the investigation in their classrooms.

YR 2 Summer Institute Experiences

In YR 2, beginning on the first morning of the six-day institute, the paleontologists helped the teachers review the aggregate data for the field site (see Figures 2 and 3.) We called it, “Digging into the Data”. The data were collected and entered by classrooms engaged in the Fossil Finders investigation the previous year. During the morning PD session scientists modeled how the data could be interpreted (and how the teachers might also interpret the data with their students) in order to develop explanations of what might have happened to organisms from one horizon (layer of rock formed from sediments deposited during a particular period of time) to another about 380 million years ago. The central scientific question centered on explaining changes in the groups of organisms over time.

Then, and this is the significant departure from what happened in the YR 1 PD summer institute experience, the scientists asked teachers to develop *their own* questions and hypotheses that they might test in the field later that day. Teachers worked in investigation teams of two to four. Most teachers struggled at first with coming up with a question and a hypothesis. During their group work scientists went from group to group and mentored the teachers, suggesting things to think about.

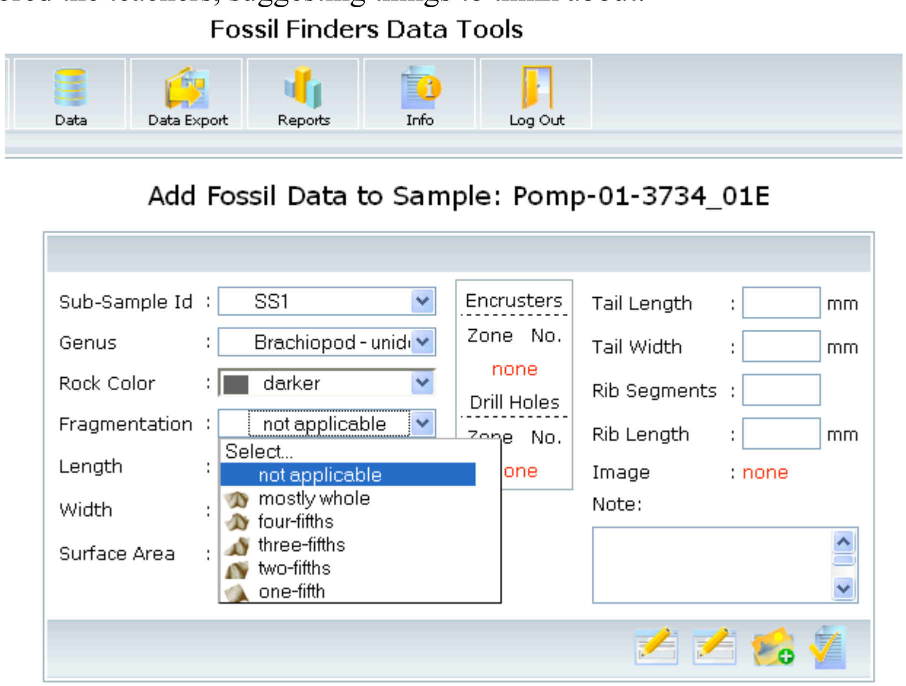

Figure 1. Screen shot of component of the project website where children and teachers submit fossil data from authentic samples.

That afternoon we headed out in vans, driving to the Fossil sample site about 2 hours away. Once at the study site teachers began to make observations of the rock outcrop and of their selected horizon in the rock. Group members worked together to collect samples to help answer their question, and discussed what they were seeing in the field. Later that evening, groups pored through their samples, many teachers staying up into the very late hours of the evening. The next day we headed back out to the fossil field. By that time, many teachers began to have a clearer picture of their research question, their hypotheses, and how and if the data they had collected the day before helped answer their question. Some groups tossed out their original question. Other groups kept or slightly modified their question and hypothesis and collected additional, or different kinds of data. (See Appendix A for schedule of YR 2 Summer Institute experiences.)

The Design of the Education Research Study

Participants. Twenty teachers from across the country were selected for the 2009-2011 cohort of the Fossil Finders project and experienced the two summer institutes as described above. Teachers agreed to participate for the duration of two years. Selection criteria included: quantity of college science courses taken, presence or absence of science research experience, teaching experience (years), quantity of science professional development, what teachers hoped to gain, their willingness to participate in the project, and evidence of a supportive school administration. These teachers were selected based on their outstanding credentials as well as their desire to improve their science teaching. For the purposes of this study we had a complete data set (as described over the two years) for 15 of the 20 teachers. These 15 teachers then comprised the participants for this education research.

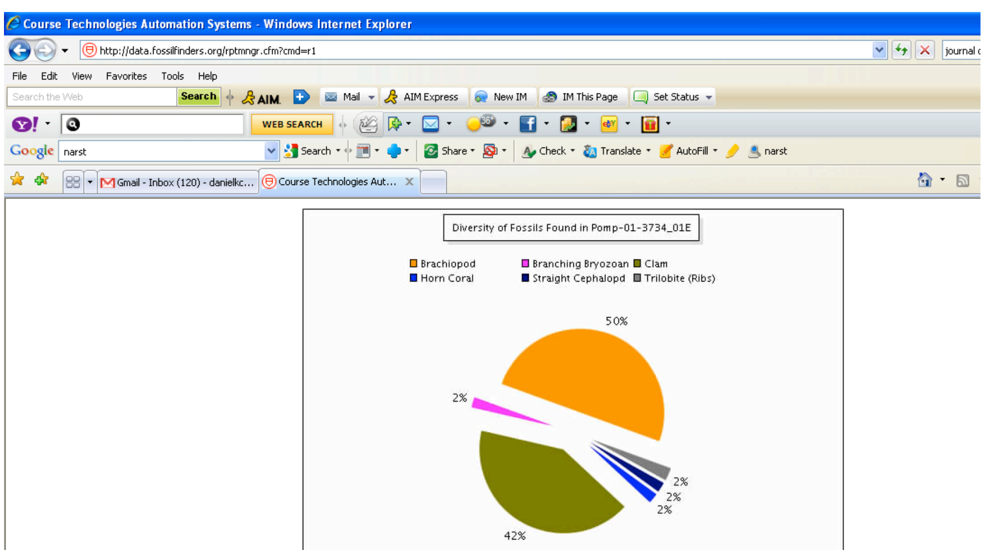

Figure 2. An example of a pie chart showing the diversity of fossils in a sample.

Data. The education study used a mixed methods approach (Creswell, 2009). The multiple qualitative and quantitative data sources included the following:

- Y1 & Y2 Pre-Post open response survey (administered at the beginning of the YR 1 and 2 summer institute and immediately following) using questions modified from the VNOS-C (Lederman, et al., 2002);
- YR 2 videotape and audio documentation of the conversations in the field and the collaboration among teacher team members and scientists;
- Written reflections of teachers to journal questions;
- YR 2 PPT presentations by teacher teams of their research during the second summer institute;
- YR 2 Videotapes of research presentations and questions from other teachers; and,
- YR 2 Audio-recorded teacher Post interviews.

Available upon request from the authors are the following: the interview protocols, examples of the Pre and Post instruments, and examples of the teachers' PPT slides.

View Reports

Statistical Report By Horizons for 3734

Horizon	Relative Abundance	Avg Fragmentation	Avg Rock Color	Clam Size Median (mm^2)	Brachiopod Size Median (mm^2)
04.1		2.9	2.3	50.0	44.5
04		2.5	2.8	168.0	60.0
03.1		3.0	2.9	108.0	64.0
03		2.4	2.8	97.0	72.0
02.9		2.8	2.8	56.0	40.0
02.8		2.9	3.0	64.0	48.0
02.2		3.0	3.1	28.0	20.0
02.1		2.4	2.9	16.1	16.0
02		2.6	2.8	35.0	33.5
01		2.8	3.4	30.0	30.0

Figure 3. Screen shot of Fossil Finders project database used to interpret the aggregate data during the teacher PD summer institute.

Data also included excerpts of the scientific discourse in the field and conversation during the evening work sessions, as teachers worked on their team research projects. We also posted reflection questions on Tapped In, the online discussion board, and prompted teachers to reflect on the tenets of NOS in connection with their PD experiences. Examples of written questions for teachers' reflection included, "In what ways might you improve on addressing aspects of NOS and inquiry in the coming year? Why do you think it is important to be explicit when teaching about NOS? Have you changed any of your ideas about NOS and inquiry since participating in the project? If yes, then please explain."

Analyses of the data began with transcribing the video and audio recordings, then conducting qualitative analyses of the transcriptions, teacher reflections and PPT presentations using the computer software, Atlas Ti (2010) and an a priori coding framework for aspects of NOS and inquiry, based on those established by the NRC (1996, 2000) and Lederman et al. (2002). We also used the scoring guide for assessing change in views about NOS and inquiry aspects from the NRC (1996, 2000) that we constructed in our previous studies (Crawford et al., 2010). Finally, we created data displays and matrices (Miles & Huberman, 1994) to look for patterns and triangulated the various data.

Results

Enhanced knowledge of NOS and Inquiry

From analyses of the multiple data sources we determined that all teachers enhanced their knowledge of NOS and inquiry, to various degrees, associated with their experiences in the summer institute both in Year 1 and in Year 2. See Figure 4.

Analysis of teacher responses to the pre-post open response questionnaire showed that after exposure to the Fossil Finders professional development and curriculum materials, teachers demonstrated a significantly more informed idea of scientific and classroom inquiry. Post-questionnaire responses had a higher mean score than pre-questionnaire responses on items asking teachers to describe and differentiate classroom inquiry and scientific inquiry. For example, in writing about scientific inquiry in the classroom, one teacher responded pre and post:

Pre: "Students have to discover the concept. That is we cannot give the students all the correct answers they have to discover the answers on their own. Students need to ask their own questions and then discover the "correct" answer."

Post: "Science as inquiry is that it should be taught through meaningful learning experiences. First the students need to be engaged. Once they are engaged we need to keep the excitement. We need the students to think critically about the concept at hand. We want them to make meaningful conclusions to what is being taught. We are not lecturing the kids and giving them the right answer. Instead they are engaged, exploring different concepts, and coming to their own understanding. This is different from traditional approaches because it requires students to think and not be passive. Science is not when students read books and write down notes, instead they work hard to make meaning. The students are not just being lectured about a cell, they are looking at a cell and making conclusions about them. Science needs to engage students to be critical thinkers not passive note takers."

In the pre-response this teacher simply stated that by using an inquiry approach students would "discover" the concept. This represents an inaccurate notion of inquiry-based teaching, in that it neglects the role of the teacher in guiding students in making sense of science principles. In the post-response this teacher demonstrates an enhanced understanding. She mentions critical thinking and engagement, and students coming to an understanding, versus discovering scientific concepts, which represents a more informed understanding of inquiry-based teaching.

Most improvement of teachers' knowledge occurred in YR 1, perhaps not unexpectedly (see Figure 4). Nearly all (or all but one – Haley) teachers with *initially* naïve and emerging understandings of NOS enhanced their views. One of the teachers, Walt, demonstrated a high level of understandings of inquiry and NOS coming into the program. Walt had studied aspects of inquiry-based teaching prior to joining the project, during a one-year sabbatical leave from his school district. Additionally, he had taken several courses in research techniques. Thus, we anticipated that Walt would start with a high level of knowledge, and we did not expect he would demonstrate a great amount of change.

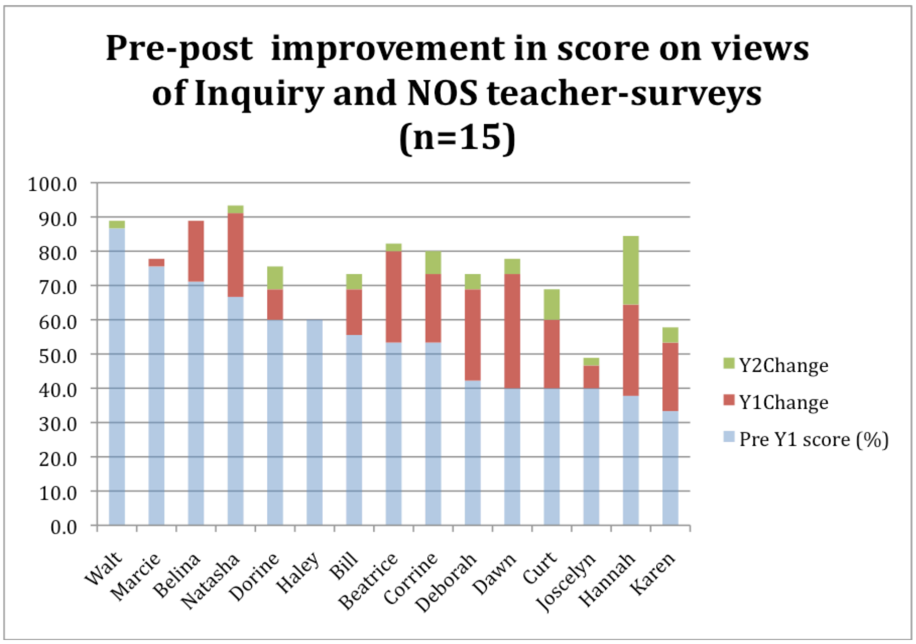

Figure 4. Change in teachers' views of NOS and Inquiry, from combined pre-post responses for inquiry and NOS questions (100% = score of 45 points).

Following the YR 2 summer institute, teachers demonstrated the most change in response to three questions (see Figure 5): #4, "Current reform documents in science education call for teaching "science as inquiry." What does this mean? How might inquiry-based science teaching look in your classroom?"; #9, "What is the scientific method? Do all scientists use the scientific method? Please explain your answer"; and #16, "65 million years ago…(see Appendix for complete question) …How are these different hypotheses possible if both groups of scientists have access to and use the same data to derive their hypotheses? Is it possible for two different scientists to perform the same scientific procedures and reach different conclusions? Please explain your answer."

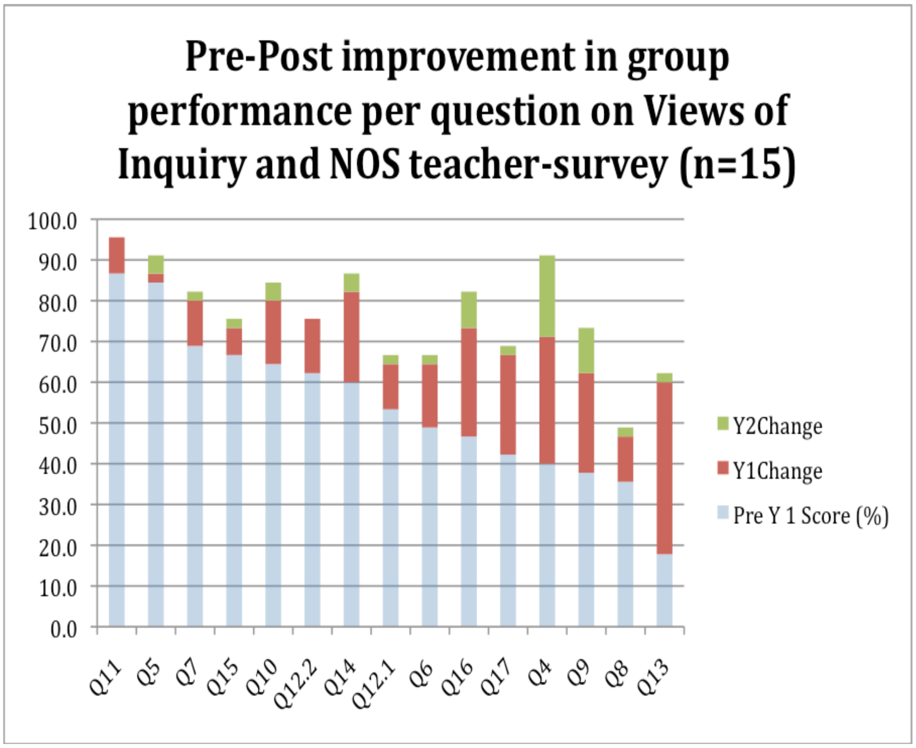

Figure 5. Change in teachers' views of NOS and Inquiry, by question (100% = score of 45 points).

<u>Changes in Views of Teaching Science as Inquiry</u>

As an example, Deborah, a 6th grade teacher with limited science background, demonstrated growth in her understanding of inquiry-based teaching. Deborah's three responses to #4 (initial, post YR 1, post YR 2) are displayed below (see Figure 6). Her initial, pre-program response only mentioned students asking questions and talking to other students, with no specific mention of dealing with the data as evidence. Her final response (YR 2) described students creating models, an important component of science inquiry.

Teacher	Pre-prior to YR 1 summer	Post YR 1 summer	Post YR 2 summer
Deborah	Students need to inquire or ask their own questions and then go about answering those questions. Students talk to other students, work in groups, use computers, hands-on activities, and/or ask me questions.	Science as inquiry encourages students to ask questions, collect evidence, evaluate the evidence, and draw conclusions or make inferences based on that evidence. Students would generate individual or class questions and then collect or generate evidence in order to evaluate the evidence. My students might wonder which populations of seeds would grow better in their terrariums and then proceed to collect evidence and make inferences and compare those with other students' inferences.	Science as inquiry involves students asking questions, collecting data and/or evidence, applying that information to current scientific knowledge, and then looking at the original question again as they discover and observe how the world works. I need to encourage student-generated questions on the topic to be covered. Then I need to creatively create ways that they can collect evidence or create models as they figure things out.

Figure 6. One teacher's responses over 2 years to 'What does teaching science as inquiry mean? How might it look in your classroom?'

In another example of enhanced views of inquiry-based teaching, Beatrice initially highlighted the use of questions. "I think that it means teaching science from the perspective of answering questions-- from a spirit of "wanting to know." Although scientific questions are key to inquiry, this was the extent of her answer. She failed to include other essential features of classroom inquiry. She gave a much more extensive response to this question after the YR 2 summer institute.

> It involves gathering data and making inferences. It can be teacher- or student-led, but I feel that student-led inquiry is often a more satisfying educational experience. Students get more out of their learning when they can see the purpose of it and when it relates to questions they've formulated themselves… Students formulate questions about the animals and observe, research, and experiment to answer their questions. Their questions almost always lead to a discussion of something that I'm "supposed" to be covering, but the students arrive at the information in a more natural and organic way-- a way that seems to lead to better retention than if I just told them all the answers."

These responses all represent improvement in these teachers' views.

<u>Changes in Views of the Scientific Method</u>

The second area of enhanced views in YR 2 related to "The" Scientific Method. In response to #9, "What is the scientific method? Do all scientists use the scientific method?" Dorine's initial view was that "It is a step by step organized process, sort of like a recipe, that helps scientists answer specific questions." After YR 2 Dorine stated, "As I learned at the Fossil Finders, but didn't know before, there isn't one scientific method. There are a number of ways scientists can use to investigate and solve questions about the natural world." After YR 2 her response included, "there is no one scientific method, it is basically a framework where an investigator can systematically obtain the answer they are researching." Beatrice's initial view was, "Yes, I think so. Without using the scientific method, a scientist's results may not be as valid," After YR 2, she wrote, "There is no one specific scientific method. There are, however, interrelated processes like gathering data and making inferences, that are used in science to answer questions." These responses all represent improvement in these teachers' views. Dawn's post interview revealed a more informed view, "I thought, because again in college I learned the five steps to the scientific method, and yet it's not five definite steps. It's a process, and the process can vary depending on what you're studying and where you are and what you're trying to learn or accomplish. It's a process or a dynamic or a fluid process."

<u>Changes in Views of Subjectivity</u>

The third area of growth in YR 2 included enhanced views of the NOS tenet of subjectivity. In response to question #16, "…How are these different hypotheses possible if both groups of scientists have access to and use the same data to derive their hypotheses?" Dawn responded initially, "Good question." She also wrote, "I have not heard the second hypothesis at all, I'm embarrassed to say. Could it be that we sometimes find what we are looking for?"

Following YR 1 Dawn wrote,

> *"…Sometimes we see what we want to see. Inferences we make are based on our scientific knowledge and background, our creativity, and our imaginations or explanations based on the data we gathered."*

After YR 2, Dawn stated,

> *"The scientists have different background experiences and prior knowledge they bring to the investigation with them. Imaginations play a big role…I would think that would be possible because the scientists may interpret or infer the data in a way based on their prior knowledge."*

The post teacher interviews and final PPT presentations provided additional evidence of teacher growth in knowledge of NOS and inquiry during the second summer institute. By the end of the YR 2 summer institute nearly all teachers achieved a level of "emerging" or higher view for most NOS aspects addressed in this study.

<u>Influence of the Nature of the Authentic Context</u>

There is evidence that the *nature of the authentic context* influenced these teachers' developing understandings of several tenets of NOS (e.g. creativity; observations and inferences, theory-laden, and that there is no single scientific method).

Besides the use of pre-post questionnaires we captured data during the fieldwork. From our observational notes and videotaped field discussions, we were able to explore the kinds of conversations teachers and scientists engaged in that impacted teacher's thinking. Besides the use of pre-post questionnaires we captured data during the fieldwork. From our observational notes and videotaped field discussions, we analyzed the kinds of conversations teachers and scientists engaged in that impacted teachers' thinking. When teachers went out into the field and actually began to gather data from the various outcrop horizons, it was at this point, that their questions and hypotheses came alive. Many groups found during the second day of fieldwork, that they had to revise their hypotheses; others completely threw out their initial ideas and started over with a new question. Here is an example of one group's research question: *Is the layer (horizon 2.1) truly gastropod-rich compared to the surrounding horizons?* Another team that began looking for evidence of high concentrations of crinoids in horizon two, based on an anomaly they observed in data collected by their students ended up discarding their initial question, when they found no evidence of crinoids in the horizon, but instead found abundant concretions, something that neither they nor their students had not noticed before. After much observation, their new question was: *Do concretions indicate a predominance of some types of fossils (gastropods vs. brachiopods…)?*

After two days in the field and an additional day for analysis, the teams presented their findings using PPT slides in a scientific conference format. During these presentations there was evidence that some teams had changed their research questions and revised their hypotheses. There was evidence teachers had begun to think in similar ways to paleontologists, and were beginning to think about scientific work with new perspectives gained from their recent personal experiences at the summer institute. There was evidence teachers began to think in similar ways to paleontologists, and began to think about scientific work gained from their personal experiences. For example, one team concluded their presentation with posing further questions, "Why are the high-spired gastropods so much more prevalent than was expected? Are these results consistent with all other horizons?" Towards the end of their research presentation the team members revealed they had "a ton of other questions from their study." One team member announced, "This is not what we expected at all." Another team member said, "In thinking about this last night, I realized there is a lot more to this, and I needed to look at the horizons (in investigating a possible correlation between color of rock and amount of fossils)."

Taking into account that these elementary and middle level teachers had varied and limited backgrounds in geology and paleontology, we were surprised to see that the teachers' final presentations reflected a depth of thinking about how science is done, beyond our expectations.

To further delve into the factors supporting teachers' growth in their views and knowledge of NOS and inquiry, we noted a particular spike in understandings in one of the 5th grade teachers, Hannah. As shown in Figure 5, Hannah began the PD in YR 1 with minimal understandings of NOS and Inquiry. Initially, she scored second to last, in this group of teachers. We developed a case of Hannah, to understand what may have contributed towards her continued growth in YR 2.

The Case of Hannah

Hannah taught 5th grade students in the northeastern part of the U.S. She admitted during the YR 1 summer institute that she had a hard time identifying the fossils the first time they were introduced. She also had difficulty with many of the geological concepts. Following the YR 2 summer institute she told her school colleagues that it "was really hard, very challenging- the summer institute; that it pushed her thinking". She was out of her comfort zone. Yet, as evidenced by her cumulative pre-post responses (Figure 4), she developed significantly enhanced understandings during her participation in the two summer institutes. After the YR 2 summer institute, her scores were the fourth highest of all the teachers. We conducted a post interview seven months after the end of the Yr 2 summer institute. Hannah reflected on her views, her experiences in the PD, and her teaching.

> Interviewer: (VIEWS AND KNOWLEDGE OF INQUIRY-BASED TEACHING) On the pre and post teacher survey that you took on-line, we asked you to define Inquiry-based Teaching. Can you talk to me a little bit more about this? **What in your view is inquiry-based teaching?**
>
> Hannah: Inquiry based teaching is hands on, but it is more than that. It is also giving kids time to think about things. It is giving them time to make observations. And…to use the data…to make explanations. I do things in the classroom outside of Fossil Finders. I think I have a much better understanding of what inquiry based learning is and I also think I understand the value of it and how powerful it is when it happens.

When asked to reflect on the use of inquiry in her fifth grade classroom, Hannah first emphasized the constraints of time and state testing.

> Interviewer: How important is it to teach about inquiry throughout the year compared to other things that you teach?
>
> Hannah: I think it is important, but then we don't have much time. It takes time. We have the state tests.

When asked to elaborate on her views of inquiry in connection with the PD, Hannah noted her changes in instruction. In the transcript below Hannah described her role as a teacher, and her changed views of how to support her children in learning science.

> Interviewer: Have your **views of inquiry-based teaching changed** as a result of participating in the FF project?

> Hannah: Yes, it did. Yes. I think that I've always tried to bring in some hands-on experiences for the children when teaching science, but that I'm more open now to not leading the instruction from the beginning, but sort of bringing in materials and sort of letting the students sort of start off with something into to the topic and leading the investigation with their questions.

One important aspect of teachers' development involved their grasp of the subject matter knowledge related to the project. Hannah mentioned constructivist teaching approaches and her enhanced confidence in teaching.

> Hannah: Well. One, I feel more confident with the subject area, and that's from revisiting it again this summer. So one of the things it makes me think about is when children learn the whole theory of constructive learning and you have these ideas, these preconceived ideas and then you come in and you get new ideas.

In reflecting on her subject matter knowledge Hannah recognized that she needs a certain level of subject matter knowledge to be able to carry out the inquiry-based instruction. She connected her subject matter knowledge with her confidence in carrying out the inquiry lessons.

> Hannah: You have to kind of figure out what's going on, so the first time you are exposed to a subject area, you don't master it. And I'm not saying that I'm a master even now, but I feel more confident with certain areas, even just names of rocks and names of fossils, and some of the features of the fossils. So, for me, I feel more confident standing up in front of the class and leading some of these lessons or facilitating these lessons.

Although we observed the interactions of teachers in the field, and listened to their talk about their experience, we could not, on our own, infer what influenced their thinking. During the post interview we asked teachers to recollect what happened and to try to correlate their learning with specific events in the PD. their learning to specific events in the PD.

> Interviewer: What do you think was the **stimulus**? (For example, did your view of IBT change more because of last year's PD, teaching the curriculum, or this summer's PD? Was there a specific part of teaching or the summer workshops?)

> Hannah: It definitely was when we went out in the field. We had to look at the data, and think of a question at the site. I think it… we were looking at the color of the rock, the shading. Yes. That was it. And then we had to come up with conclusions and make a presentation.
> …I definitely think it was the time we had to come up with our own questions in the field. We had to look into the data. When the scientists from PRI had us look at the data, and we had to ask a question, it was when we had to really look at the data.

In an effort to further understand the impact of the field experiences, and teachers' perceptions of the open-inquiry, we asked teachers to describe the group inquiry project.

> Interviewer: (DOING SCIENCE) Give me a brief **summary of your group's research project** at Pompey. Did that experience help you understand **what paleontologists do**? (the practice of paleontological research) Can you remember **what part of the experience helped you better understand that**?
>
> Hannah: I cannot remember all that we did, but I know that we struggled with coming up with a question. We looked at the rocks. I definitely learned more about what paleontologists do. Of course, our project was very small. It was just a part of what paleontologists do. But then, we learned about how they need a lot of data and look at broad questions.
>
> Interviewer: Do you have any examples of practicing scientific discourse from your experiences in the FF PD this year? For example, in the field, during group work in the evening, etc.
>
> Hannah: In the field during the research experience definitely, because there was debate about the color of the rocks. You know, what do you see it as, well I see it more as this… which samples should we use to illustrate this number shade? It was debate before there was consensus over what we should use. you know. There was debate and consensus as to what language we should use in our presentation, there was definitely debate about vocabulary and language use to what was the question we were going to answer.

When asked about her understanding of NOS, Hannah demonstrated clear growth in understanding about NOS on the post-open response questionnaire taken immediately after the summer institute, yet when asked about her views of NOS in an interview well after the summer institute, at first she struggled to remember all the tenets of NOS.

> Interviewer: (VIEWS OF NOS) We've been talking about teaching NOS for the last two years. We know it's a difficult concept to grasp. What in your view are some important aspects of NOS**?** Are there particular aspects that resonate more than others? Are there particular aspects that are still foggy or too abstract?
>
> Hannah: Oh, you mean about observations and inferences. I cannot really remember the list. But, I know that now I talk to my students about that, now that is the way scientists work. I have definitely changed the way I talk to my students about how scientists do science. The program really helped me with that.

Hannah described above how she had changed her way of talking with her students. From her statement, she tried to make explicit NOS in her teaching.

> Hannah added…To try to get them to think a little more in a scientific way, but that's an opportunity for me to just bring out the NOS. So, if I didn't know about it (prior to the PD), I would probably let them do an experiment and not even comment.

Hannah talked extensively about the teacher designed inquiry project and her groups' field experiences. She described what her group did, the kinds of questions they asked, and the discourse as they carried out their investigation.

> Hannah: You need to have a lot of information before you make a prediction or a hypothesis about something. So, there were several opportunities whether we did the pterosaur or the research opportunity, or even if we were just looking at an impression in a rock and trying to decide what you think…well, I think it's facing this way, and I think that's an eye, and I think that's not an eye…,
>
> There was a high level of interest and a high level of knowledge and people were very, I thought, really highly focused on learning.

Finally, we asked teachers about their ideas about teaching evolution. The following is Hannah's response.

> Interviewer: (VIEWS/UNDERSTANDINGS OF EVOLUTION) Has your **understanding of evolution changed** through participating in Fossil Finders?
> If so, in what ways? Are there any others?
>
> Hannah: I'm sure there are many aspects that I'm still unclear on. I'm not struggling with it, but if I had to explain it, I'm sure there are a lot of things that I don't know. But, it's not a struggle for me because I accept it.
> …I already believe in evolution,

Hannah discussed the role of evidence related to evolution.

> Hannah: This project gave me a better insight into the evidence- the fossil evidence, and what could be used for evidence. And, why it is important for students to understand some of the beginnings of how you use evidence, so they can better understanding evolution later on.…what I did get so much of was that there's evidence of evolution. And so we concentrated on let's look at what life was like back then. Then let's look at what life is like now, let's look at what we can see has changed, and how it has changed and how it is still connected to what it was back then and sort of see it in stages.
>
> I had never really done that; I just sort of accepted by reading books that I believed in evolution, but I never really looked at anything that supplied evidence for that. So, I would say that, because I had the opportunity to work with fossils, as well as visit the museum which had a lot of interesting exhibits, that was hands on and fossils in cases, and other things that gave

> me a greater understanding and a greater breadth or wider understanding or depth of what evolution is or was or used to be and how things evolve. So I would say yes, it widened my understanding but it didn't change it.

In summary we have multiple forms of evidence that all teachers enhanced their understandings of inquiry and NOS during the two-year PD experience, although to various degrees.

Discussion

Related to supporting teachers' understandings and views of inquiry and NOS, the areas that showed most gain by the group included articulating the meaning of inquiry-based teaching; understanding that scientists use different methods depending on the question; that science is subjective; and the role of subject matter knowledge. Possibly, the most interesting results and insights come from analyzing the qualitative data. In thinking about what may have contributed to these results it is important to consider the nature of the authentic scientific investigation in this PD.

In Hannah's case she professed to have a better understanding of inquiry-based teaching, She attributed her enhanced understanding of inquiry and NOS to the group field investigation where they researched their own questions. " We had to look at the data, and think of a question at the site." It is important to point out that Hannah began the program with limited subject matter knowledge, views of inquiry and NOS. Yet, she grew in her understandings, as well as her ideas of what was possible in her classroom. In talking about teaching evolution she stressed the fossil evidence, and how she might involve her students.

We observed many interesting and positive outcomes from the teachers' working on their own research questions, during the summer institute. Some of these appear below:

1) Teachers demonstrated an ability to come up with a hypothesis, design an investigation, and devise a plan to test the hypothesis. In addition, and perhaps more importantly, teachers were willing and able to revise their hypotheses and investigation designs as they conducted their work in the field. All very much in common with what "real" scientists do.

2) Teachers invented procedures and tools, in the process of carrying out their investigations. Color charts are an excellent example of this – highlighting both the creative and subjective NOS, and demonstrating their placing value on communication and explanation.

3) Teachers explored further and learned on their own, using resources in the museum and additional readings. A major theme in the data was the importance of subject matter knowledge in framing the research problem and evaluating its results, and the teachers seemed to come to appreciate this component of understanding.

4) Teachers referenced their own teaching and their students, and it was apparent that the *relevancy* of the scientific investigation to their own classroom teaching was important to them. In their post interviews, teachers felt “better equipped” to support students in the Fossil Finders investigation and in conducting other investigations throughout their curriculum having had this “real-world” experience themselves.

5) In the scientific conference teams, without prompting, teachers noted connections between their own study and that of other groups, and asked other teams questions about the science research, highlighting the role of (again) scientific knowledge and modeling the context of a community of practice.

Several themes emerged from looking across the data related to the YR 2 summer experience.

First, teachers (7 of 15) indicated they were *better equipped to teach the subject matter* of the FF investigation, through the authentic experiences. In the context of carrying out the investigation they became more adept at discussing fossils, rocks, colors, layers, etc.

> Jocylen: And I’m feeling now, though, that as they are sifting through the rock and looking at fossils, and talking about color, **I feel better equipped to help them find answers to their questions.** I think that that is a really important and relevant byproduct of FF. (Post Interview Transcription)

> Dawn: Yes, I could have read all of that in a textbook and I never would have gained the knowledge of how the sizes varied greatly from layer to layer, and how the density of fossils varied. **You were out there and you saw and you experienced** and some groups were coming back with all kinds of fossils while other groups were finding nothing but those teeny little, I don’t remember what they were. And then there were other groups that found nothing. **And you can’t read that in a textbook. To see it to live it, gave me a whole greater understanding**. (Post Interview Transcription)

A second theme that emerged was that teachers (7/15) stated they gained better understanding of the idea that *scientific investigations are guided by scientific knowledge.* Evidence supporting this theme includes these statements from Haley and Deborah.

> Haley: I know now, …what it takes to go out and harvest the rock. Decide where you will take it from. It takes different factors. **You need to research before you do your research. Um. Making choices and what direction you’ll go with it. And then, coming up with that plan.** (Post Interview Transcription)

> Deborah: Based on our evidence we began the process of explaining what we observed and what it might mean. **During that process we discovered we needed to have a great knowledge of the science we were studying. We asked the scientists at hand questions and looked through our reference books.** We

> discovered that we needed to use creativity in our question, evidence collection process and even in the explanation. (Fieldwork Reflection)

A third theme emerging from data analyses was that teachers (6 of 15) clearly began to think about *multiple methods of science versus a single method or* better understanding of “The” Scientific Method.

> Karen: My partner and I had identified some questions that we thought could be answered through scientific investigation after studying the data reports in class. Once we were in the field, and collected rock samples, took them back to the dorm to critically and logically make the relationship between evidence and explanation, we seriously had to change our focus. Our evidence reshaped our thinking, therefore, the question was reshaped as well. (Fieldwork Reflection)

A fourth theme that emerged was better understanding of the *empirical basis of science and the role/use of existing data (in the database) in generating questions,* as indicated in 3/15 of the teachers responses.

> Hannah: …what they [students] could do when all is said and done is that they could look at the databases; **from the database they could sort of make their own explanation.** Try to think, why might this information be important. What can we learn from this part of the database? And that’s a huge database that is being put together by the museum.

A fifth theme was an understanding of *the creativity tenet of NOS,* as evidenced in 3/15 responses

> Deborah: **We discovered that we needed to use creativity in our question, evidence collection process and even in the explanation**. Gathering the evidence required trial and error and **we developed creative ways of marking off sections of the rock.** In the process of this fieldwork we not only struggled with our initial question, but developed more along the way. It was uncomfortable at times and didn’t leave us with an absolute answer which is how real science works, I suppose! (Fieldwork Reflections)

A sixth theme was better understanding of the *role of the scientific community in developing knowledge* (3/15).

> Walt: I don’t remember the exact discussion but I know that when we were doing the research project, there was a lot of discourse that went on. There was discourse when we were deciding which horizons to collect with the whole group because we were discussing which ones would be more interesting. And there was discussion during the presentations…There was a lot of negotiating. Some of it was a decision about what we were going to analyze; we had decided to analyze several different horizons - looking for

> changes that might indicate why there was a change in the number and the percentage of brachiopods vs. clams. So, then we had to discuss which aspects to look at. And we decided to basically look at everything. So, let's see, there was a big debate and negotiation on how we would number the horizons. Where we would start. And how far we would go. (Post Interview transcription)

From the literature there are various ways to provide teachers with inquiry experiences. In one study of preservice teachers, participants had opportunity to design investigations in college classroom settings as they prepared to become teachers (Windshitl, 2003). In other studies of traditional summer research internships (i.e. RETs) teachers work in a laboratory setting shoulder to shoulder with a scientist/doctoral student. Usually these investigations depend on using a controlled experimental design (i.e. Patel, Trumbull, & Crawford, in preparation).

In the PD reported here we engaged our teachers in a different kind of setting—that of paleontological fieldwork-- versus primarily laboratory work. In contrast to using controlled experimental methods based in the laboratory, teachers made observations in the field and used these observational data to reconstruct an environment of the past. Further, they asked their own questions, proposed hypotheses developed their own methods, gathered fossil data, looked for patterns in the data and developed explanations and answers to their questions using data as evidence. Finally, they justified their explanations in a public forum.

In this PD teachers personally experienced what it means to do science. All teachers grew in their knowledge of NOS and inquiry. There is evidence teachers began to understand that in science, one question may likely lead to another question. In many some cases the teachers in this study began with very low levels of understandings of NOS and Inquiry; but all teachers demonstrated significant growth towards a more informed perspective regarding NOS and Inquiry. (Also see, Capps and Crawford, 2011). The results of this study support the importance of guided attention to and reflection on NOS in the context of the authentic scientific research experiences (Schwartz et al. 2004). As in the Schwartz et al. (2004) study, these teachers reflected on these experiences through journal responses, written and oral questioning, and discussion.

Yet, the PD context went beyond that provided in the Schwartz et al. (2004) study. In each case, teachers had opportunity to ask their own questions, design and conduct an investigation, work collaboratively, grapple with the data, redesign and sometimes, even throw out a question, create their own methods and tools, and develop explanations based on the evidence. Scientists guided teachers as they developed their research study. Finally, teachers defended their explanations in a forum of peers and experts.

An important point is that in this PD the authentic context had direct relevance to these teachers. The research site was the same one in which they would involve their own students. The relevancy of the authentic context is an important deviation from Schwartz et al. 2004 study and many authentic PD experiences for teachers.

Conclusion

There is evidence that for these 15 teachers, the particular context and the tasks in which the teachers engaged contributed to developing understandings of NOS and inquiry. The context of the PD was the authentic Devonian fossil investigation accessible to teachers and students. The tasks included creative hypothesis development and testing and drawing conclusions from the evidence. Following this experience the teachers demonstrated enhanced knowledge of many of the tenets of NOS e.g. creativity; observations and inferences, the tentativeness of science, the empirical aspect of science, and the view that there is no single scientific method. It is noteworthy that in YR 2 the total length of time given to the teachers to come up with a researchable question, develop a hypothesis, and actually begin to test that hypothesis was quite short, indeed—about 3 days. The field research provided fertile ground for creativity, as teachers thought up new questions, generated hypotheses, collected data, made revisions to their questions and how to collect the data, then collected more data, and used the data as evidence in testing their hypotheses. The non-linear nature of their scientific methods ("method" with an "S") came alive for the teachers, as they experienced science and wrestled with asking and answering questions. Additionally, the PD leaders made explicit the connections between what they did in the field and NOS. Further, teachers had opportunity for critical reflection.

This study suggests a PD model in which teachers with limited formal science coursework can engage in authentic science, with an emphasis on reflection, and brought along to a point where they understand and begin to teach about inquiry and NOS. An important aspect of the PD was that the authentic research task, for the majority of the teachers, mapped exactly onto the curriculum they had previously taught (the school year before), and would teach in the coming year. Thus, there was good alignment and in fact, a very close match between the summer PD research experiences and participants' future teaching in their classrooms. The context of the scientific study directly connected with teachers' own future lessons. As they engaged in the authentic scientific work, these teachers thought about their classrooms and their students. The PD research experience was targeted and intense, authentic to scientists, as well as teachers, as well as relevant to classroom inquiry.

These findings have implications for the possibilities of how to feasibly and effectively develop PD experiences for in-service teachers, in order to support them in developing understandings of NOS, an area that continues to be challenging and important. By situating teachers in authentic experiences in the field, in the kind of science that is not just about controlling variables in a lab setting, and by allowing these teachers opportunity to be creative and engage in actual scientific work – work that also has relevance to their teaching (the research aligned with what they would later engage their children), in addition to giving them insights into the philosophy and goals of the project, we gave teachers the opportunity to develop their personal understandings of inquiry and the nature of science.

Significance

We believe these results connect strongly with the 2011 NARST theme—Global Sustainability and Public Understanding of Science: The Role of Science Education in the International Community. It is critical for teachers in the USA as well as other countries to understand what science is, if they are to enact science inquiry in their classrooms and teach students about inquiry and NOS. Thus, we believe our findings relate to effective professional development strategies for enhancing teacher knowledge of Inquiry and NOS; and that this has implications for educating all children, all learners, and all future citizens, in developing their understandings of science.

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APPENDIX A

Agenda for Fossil Finders Professional Development Summer 2010 (August 8-13)
Year 2 for Cohort P-2

Sunday, August 8, 2010

T I M E	What (and who will be doing some of the major things)	Where
2:00 pm - 3:30 pm	Arrival & Check-in for P2 Teachers *Choose sandwiches for Monday afternoon *Read over focus group questions	Cascadilla Hall
3:30 pm - 5:30 pm	Focus Group Interviews	Cascadilla Hall
6:00 pm – 7:30 pm	**Welcome Dinner**	Local restaurant
7:30 pm- 9:00 pm	Revisit NOS/Inquiry: Making explicit connections	Cascadilla Hall

Monday, August 9, 2010

7:30 -8:30 am	Continental Breakfast-Discussion of experiences with Fossil Finders curriculum. *Briefly discuss expectations for year 2	Cascadilla Hall
8:30 am – 11:30 am	Digging into the data- use of database to make interpretations; Materials needed: Computers	Snee Hall, Rm. 2146
11:30am 1:00pm	Lunch: delivered to SNEE at 11:00, sandwiches distributed and eaten in van on way to Fossil Fieldwork Site	
1:00-6:30pm	Fieldwork: Understanding the Devonian (brief review of the Devonian in NY to help teachers get their heads back into FF); Materials needed: Comfortable clothes for the field, sunscreen, hat, water	Pompey, NY
7:00 pm - 8:30 pm	Working dinner (Pizza): Begin working with new field data	Cascadilla Hall

Tuesday, August 10, 2010

8:00 am – 11:00 am	Pick up bagels and coffee and turn in sandwich order 7:00am 8:00-10:15-Video Cases of inquiry- 10:15-11:00- Video cases of NOS	Cascadilla Hall Snee Hall, Rm. 2146
11:00 am – 6:30 pm	*Lunch in Field (Delivered to Cascadilla at 10:30) Fieldwork: Collecting data and testing hypotheses Collecting bulk samples Extra time: Cherry pick/take pictures	Pompey, NY
7:00pm -8:00pm	Dinner: Taste of Thai Express	*Cascadilla Hall*
Post-dinner	Independent reflection (thinking about thinking): *Tapped-In (Due Thursday AM)*	Independent work on computers

Wednesday, August 11, 2010: Authentic Science in the Classroom

8:00 am - 11:30 pm	Pick up bagels and coffee 7:00 a.m. Vans leave for PRI @ 7:50 a.m. 8:10-10:00- Pulling Pompey together: 1) Finish up work on Pompey 10:15-11:45- ELL Session- Constructional congruency framework	*Cascadilla Hall*
11:45 am - 1:00 pm	Catered lunch – time for teachers to peruse museum on own.	*PRI*
1:00 – 4:00 pm	Lesson Plans: Begin working on lesson plans.	*PRI*
4:15 – 5:45 pm	The Museum of the Earth Tour	*PRI*
6:00-7:00pm	BBQ Chicken Picnic Dinner AT PRI	*PRI*

Thursday, August 12, 2010

8:00am - 12:00pm	Pick up bagels and coffee 7am 8:00-8:30- Written responses to probe on evolution 8:30-10:30- Present their findings from scientific investigations to the group. 10:30-12:00- Continued work on lesson plans	Cascadilla Snee Hall
12:00pm - 12:45pm	Viva Taqueria: Pick up and bring to Snee Hall	Snee Hall, Rm. 2146
12:45pm - 5:45pm	-12:45-1:45pm Translation with P1 teacher, JD 2:00-3:30- Transference -3:30-5:45- Field Trip: CHANGE OVER GEOLOGIC TIME AND DISTANCE	Snee Hall, Rm. 2146 Portland Point
Dinner	Dinner on your own, meet over dinner and discuss lessons. Save dinner receipts up to $15. Enjoy Ithaca!	
Evening Activity	Work on lessons for tomorrow morning	

Friday, August 13, 2010

8:00 am –11:00 am	Pick up bagels and coffee and turn in sandwich order 7am Teachers model their designed lessons. EACH GROUP DOES A 20-minute section and receives feedback from others	Cascadilla Hall Snee Hall, Rm. 2146
11:00 am - 12:30 pm	Scheduling, questions, research aims and expectations, etc…. time to talk about FF in the classroom.	Snee Hall, Rm. 2146
12:30 pm - 1:00 pm	Lunch (pre-order sandwiches)	Snee Hall, Rm. 2146
1:00pm- 2:00pm	Closure	Snee Hall, Rm. 2146

*For field trips, vans will leave campus from the Eddy Gate behind Cascadilla Dorm. Please remember to bring appropriate clothing (closed-toe shoes).

APPENDIX B

Fossil Finders Teacher Views of Science Questionnaire
Please answer the following questions without using any outside resources.

1. How would you describe your role as a science teacher?

2. Describe the predominant teaching strategies you use and explain why you use them.

3. How do students learn science best?

4. Current reform documents in science education call for teaching "science as inquiry."
   - What does this mean?
   - How might inquiry-based science teaching look in your classroom?

5. Do you think there are benefits to using inquiry-based science instruction?
   - If so, why and what are the benefits?
   - If not, why not?

6. How might classroom inquiry compare to scientific inquiry?

7. How confident are you in your ability to teach science as inquiry? Please explain your answer.

8. Does science always involve doing experiments? Please explain your answer.

9. What is the scientific method?
   Do all scientists use the scientific method? Please explain your answer.

10. What does the word *data* mean in science?
    Is *data* the same as or different from *evidence*? Please explain your answer using examples.

11. Are *observations* the same as or different from *inferences*? Please explain your answer using examples.

12. What is a scientific theory?
    After scientists have developed a theory, does the theory ever change?
    - If yes, what is the process by which a scientific theory may change?
    - If no, please explain why scientific theories do not change.

13. Is there a difference between a scientific theory and a scientific law? Please explain your answer.

14. Is there a role for creativity and/or imagination in scientific investigations?
    - If yes, then at which stage(s) (i.e., planning and design; data collection; after data collection) of an investigation might a scientist use imagination and creativity? Please explain your answer using an example.
    - If no, please explain why not and provide an example.

15. Is the work of scientists influenced by society? Please explain your answer using an example.

16. Scientists think that about 65 million years ago dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two are widely supported. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago, beginning a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction.

- How are these different hypotheses possible if both groups of scientists have access to and use the same data to derive their hypotheses?
- Is it possible for two different scientists to perform the same scientific procedures and reach different conclusions? Please explain your answer.

17. Explain the process a paleontologist might use to research how climate has changed throughout the geological past in NY.

APPENDIX C

Backgrounds of 15 Participants (P-2 Teachers)

Teacher	Grade level	State	Education	Teaching (Yrs)	College Sci Courses	Research Exp	Sci. PD Exp	Gende
Walt	8th	NY	MS-Biochemistry	13	20	Yes	3	M
Bill	5th	NY	BS-Electrical Eng.	14	15	Yes	2	M
Deborah	6th	IL	BA-Elementary Ed	4	3	No	0	F
Curt	8th	LA	BA-Elementary Ed	9	10	Yes	1	M
Jocylen	5th	PA	BS-Elementary Ed	2	7	No	2	F
Belinda	7th	CA	BA-Fine Arts	10	7	Yes	4	F
Dawn	6th	NY	BS-Physical Therp	19	4	No	8	F
Dorine	8th	NY	BA-Anthropology	5	16	No	3	F
Corrine	6th-8th	FL	BS-Elementary Ed	22	9	No	3	F
Natasha	7th	IL	BS-Biology	5	16	Yes	0	F
Hannah	5th	MA	BA-Education	20	2	No	3	F
Karen	5th	MA	BS-Education	23	1	No	1	F
Marcie	7th	CA	BA-Bio/Chem	22	32	Yes	4	F
Haley	7th	NE	BS-Elementary Ed	32	7	No	10	F
Beatrice	6th-8th	PA	MS-Entomology	6	18	Yes	2	F