The Impact of Full Immersion Scientific Research Experiences on Teachers' Views of the Nature of Science

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Abstract

This study examined secondary science teachers' conceptions of the *nature of science* in full immersion authentic scientific research programs. The study compared teachers' conceptions in full immersion scientific research programs with and without explicit nature of science instruction. For 8 weeks in the summer, 19 teachers in Trial A (non-explicit) and 21 teachers in Trial B (explicit) were paired with research scientists and lived on campus in order to participate fully in scientific research. In Trial B, teachers met weekly for a 2-hour group session with activities to explicitly address the nature of science. Data included pre/post internship Views of the Nature of Science (VNOS-C) questionnaires, interviews, and videotapes of group sessions. In contrast to the minimal advances made by teachers in understanding the nature of science in the non-explicit group (Trial A), the explicit (Trial B) teachers made substantial gains in understanding the nature of science. However, the Trial B teachers' perceptions of the nature of science were still ambiguous in specific aspects of the nature of science. The explicit nature of science instruction in Trail B was (1) effective in initiating positive shifts in teachers' understanding of nature of science, but (2) limited in reflection opportunities for teachers to challenge their nature of science understanding in the context of authentic science research experiences.

> *Science is inevitably socially embedded. As a practicing scientist, I believe, as we must, that there is an external truth out there. I also believe that science bumbles along fitfully towards knowledge of that external reality. And that is socially embedded and is inevitably so because it is done by human beings and not robots.* Stephen Jay Gould, (1987)

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Introduction

Scientific literacy requires both scientific knowledge and understanding of the "fitful" processes by which scientific knowledge is developed (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996, 2000). Recognizing the human element of the scientific endeavor is a cornerstone to understanding the *nature of science* [NOS]. Knowledge of NOS as it relates to science subject matter and scientific inquiry is a valued component of scientific literacy (AAAS, 1993; NRC, 1996). Thus, knowledge of NOS is an essential component of science *teaching* literacy. The science education community continues to embrace this focus and seek effective practices of incorporating NOS as part of teacher education and professional development.

Examples from the classroom may help illustrate the importance of addressing NOS and NOS pedagogy in teacher education and professional development. In Texas, for example, a 9th grade biology student discovered a previously unknown species of fresh-water crustacean in the intermittent rain-water pools found in the pink granite batholith called Enchanted Rock, near Fredericksburg. That this was a newly discovered species was confirmed while the student was studying the organism with an invertebrate zoologist who was an authority in crustaceans. However, when the student presented the discovery at his school's science fair, he lost points for not having a "control" in his project (Dr. Sandra West, personal communication, 08/15/03). Even though the project was based on appropriate and valid descriptive science methods, the student had not conformed to the traditional "Scientific Method" that was expected. Due to teachers not being aware that valid scientific investigations may follow a descriptive approach, many teachers often inappropriately expect controls in investigations that do not require controls, or where controls are unattainable. The prevalence of this misconception is astounding, as illustrated by a simple search of the Internet for information regarding science fair projects and the scientific method. The search hits upon over 1 million sites.

Another example concerns teachers' and students' misunderstanding and misuse of scientific terminology. For example, referring to evolutionary theory as "just a theory" implies that a scientific theory is little more than an educated guess or opinion rather than a well-substantiated explanation for a phenomenon (McComas, 1998). Like "the scientific method," views about science as objective and value-free prevail (Lederman, 2007). Teachers with limited understanding of NOS and NOS pedagogy are ill prepared to promote scientific literacy in their students. Thus, efforts to improve NOS views of K-12 students must involve increased efforts to address teachers' NOS views and pedagogical knowledge (Lederman, 2007).

The purpose of this study was to assess secondary science teachers' NOS learning during a summer professional development program that involved full immersion authentic scientific research with and without explicit instruction. This study was done in response to a comparison of NOS learning outcomes in different programs for pre-service and in-service science teachers that involved science research experiences (Westerlund, Schwartz, Lederman, Garcia, & Koke., 2001). The collaborators in this study included research scientists and science education researchers with experience in summer research internships, and a science educator with experience in NOS instruction and analysis. The design of the NOS instruction stemmed from research-based recommendations (Lederman, 2007). Although prior studies have examined NOS learning outcomes related to science research internships (e.g. Bell, Blair, Lederman, & Crawford, 2003; Schwartz & Crawford, 2004; Schwartz, Lederman, & Crawford, 2004; Westerlund, McComas, & Schwartz., in press), little is understood about impacts of a full immersion research experience, where teachers take ownership for developing and conducting a research investigation as part of a scientist's research group.

What is Nature of Science?

Historians, philosophers of science, and science educators affirm various representations of NOS (Lederman, 2007; Loving, 1997; Matthews, 1994). However, certain common aspects of NOS are agreed upon as relevant to the K-12 science curriculum and students (Abd-El-Khalick & Lederman, 2000; Clough, 2006; Lederman, 2007; Millar & Osborne, 1998). Among these are that scientific knowledge is (a) not based on dogma, but can be re-examined and verified; considered durable, but can be revised or replaced (i.e. science is inherently *tentative)*; (b) based upon *empirical evidence* (observations of the natural world); (c) developed within the framework of prevailing concepts (*theory-laden* observations and interpretations) and influenced by *personal subjectivity* due to scientists' values, knowledge, and prior experiences; (d) requires human thought and imagination (*creativity*); and (e) influenced by the culture in which science is conducted (*socio-cultural embeddedness*). Also, NOS considers the complementary roles of *observation* and *inference* in the development of scientific knowledge and the validity of *different methods* of developing scientific knowledge such as descriptive (observational), correlational and experimental. Furthermore, understanding the *difference between scientific theories and laws* relates to learners' conceptions of different types of scientific knowledge, as well as conceptions of the inherent tentativeness of that knowledge (AAAS, 1993; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; NRC, 2000). We explore teachers' understandings of these eight tenets in this study. An understanding of these NOS tenets can be developed in the context of any scientific discipline since the desired level of understanding represents NOS across science disciplines (Schwartz, Lederman & Lederman, 2008).

Review of the Literature

Developing Teachers' Nature of Science Conceptions through Science Inquiry Experiences

Even after repeated attempts to improve the teaching of NOS, teachers and students continue to lack a complete understanding of the concepts or pedagogy (Duschl, 1990; Gallagher, 1991; Lederman, 2007; Meichtry, 1992). Similarly, teachers' conceptions of science as inquiry often vary and may not concur with advocated views (Bybee, 2000; Roth, McGinn, & Bowen, 1997; Schwab, 1978). The challenge for many teachers and students to fully understand NOS and scientific inquiry may be due to not having scientific inquiry experiences upon which to base their understanding (Gallagher, 1991; Roth et al., 1997; Schwab, 1978). It has been suggested that by having teachers engage in scientific inquiry activities similar to those of scientists, or alongside scientists, they should develop a fuller understanding of nature of science and the methods by which science progresses (Gallagher, 1991; NRC, 1996; Roth et al., 1997; Schwab, 1978; Welch, Klopfer, Aikenhead, & Robinson, (1981). Participation in research in scientific laboratories immerses teachers in the culture of science. Asking questions, writing proposals based on library research, learning techniques, designing new protocols, using new scientific vocabulary, analyzing data, presenting results, and being with research scientists, graduate students and technicians on a daily basis are all part of the culture of science. Through immersion in this culture, teachers join a community of scientists and come to understand science not from an abstract textbook-oriented perspective but through scientific inquiry in an authentic experience. By learning scientific knowledge through inquiry, teachers may begin to think differently about how science is conducted and the possibilities of how science may be conducted in the science classroom. Science research experiences can also provide a beneficial context for learning about NOS.

Preservice and in-service teachers who have participated in short term research activities with scientists and with explicit NOS instruction have been successful in developing a fuller understanding of NOS (Calvin & Gilmer, 2008; Lederman, 2007; Schwartz & Crawford, 2004; Schwartz et al., 2004). Use of historical and contemporary case studies of scientific research, along with explicit NOS instruction, has also yielded enhanced NOS views (e.g. Irwin, 2000; Wong, Kwan, Hodsun, & Yung, 2009). Classroom-based scientific inquiry has led to enhanced NOS views when the lessons also include explicit attention to NOS aspects (e.g. Abd-El-Khalick & Akerson, 2004; Akerson & Hanuscin, 2007; Gess-Newsome, 2002; Khishfe & Abd-El-Khalick, 2002; Lederman, Schwartz, Abd-El-Khalick, & Bell, 2001; Morrison, Raab, & Ingram, 2009). The literature clearly demonstrates the need to include explicit and reflective learning opportunities for NOS in the context of science inquiry experiences. Simply "doing inquiry" alone does not necessitate enhanced views. However, the aforementioned literature involving teachers' inquiry experiences in classroom settings and authentic science contexts lacks examples of a full-immersion science research internship where teachers assume the responsibility for their own investigations within the science community. Such a study is needed to enable comparison of learning outcomes in various inquiry contexts. The current study was conducted to fill this need by examining nature of science learning outcomes from a full-immersion science research experience for in-service secondary science teachers.

Teacher Learning through Professional Development

Research that examines the relationship between professional development and teacher learning, teaching practice, and student learning has been the focus of reviews (e.g. Loucks-Horsley, Hewson, Love, & Stiles, 1998; Loucks-Horsley & Matsumoto, 1999; Putnam & Borko, 2000). Loucks-Horsley et al. (1998) described strategies of professional development for science and mathematics teachers. Relevant for the current study are the categories of "immersion" and "collaborative work." "Immersion" involves teacher participants "doing" science. The immersion experiences of the teachers in the current study involved teachers becoming part of a research group where they designed and conducted scientific research that was relevant to the authentic science community.

Authentic scientific research is generally characterized by features that include (1) "the process of formulating and testing hypotheses," (2) the development of an experimental or descriptive design, (3) the obtaining of evidence by "observations and measurements taken in situations that range from natural settings to contrived settings," (4) the roles of logic and creative insight in the analysis of data, and (5) the development of an explanation that is based on observations (AAAS, 1989, p. 26-27). The immersion model is similar to apprenticeship models as described by Brown & Melear (2007) and Roth & Tobin (2002). "Collaborative work" involves teachers building partnerships with each other, scientists, and science educators. A sound collaborative can enhance teacher learning and, subsequently, teacher practice. By providing teachers opportunity to confront their ideas, examine new ideas, and share with others, professional development experiences become effectively centered on the teacher and "teacher community" as learner (Loucks-Horsley & Matsumoto, 1999).

We also consider "context" a critical element for teacher learning in general (Borko, 2004; Loucks-Horsley et al., 1998; Putnam & Borko, 2000), and learning of NOS specifically (Schwartz & Crawford, 2004; Schwartz et al., 2004). "How a person learns a particular set of knowledge and skills, and the situation in which a person learns, become a fundamental part of what is learned." (Putnam & Borko, 2000, p. 4). Regarding NOS as a learning outcome, the current study examines teachers as learners within a context that involved the authentic and social context of the institute (Lave & Wenger, 1991).

Summer Science Institutes

A variety of models have emerged that involve teachers in scientific research. Outcomes regarding science content knowledge and attitudes toward science are encouraging. Specifically outcomes for teachers in full immersion science research internships include: (1) increased science content knowledge and skills, (2) increased enthusiasm for science, (3) expanded opportunities for participation in scientific dialogue, (4) effective changes in their students' attitudes toward science, and (5) satisfaction with research programs. (Bazler, 1991; Beighley, 1998; Boser, Faires, Slawson, & Stevenson, 1988; Brown & Melear, 2007; Calvin & Gilmer, 2008; Kielborn & Gilmer, 1999; Westerlund, Garcia, Koke, Taylor, & Mason, (2002). Participants of summer programs also indicated that they increased their laboratory demonstrations and activities in their classrooms as a result of their research experiences (Bazler, 1991; Boser et al. 1988; Calvin & Gilmer, 2008; Frechtling, et al. 1995; Kielborn & Gilmer, 1999, Westerlund et al., 2002).

While enthusiasm and support for engaging teachers in science research internships seems to be growing over the last decade, little has been reported concerning NOS learning outcomes of these types of programs. One study, Project ICAN: Inquiry, Context, and Nature of Science (Lederman, Schwartz, Lederman, Matthews, & Khishfe, 2002), teachers spent a few hours a day for two weeks working with and observing scientists in their laboratories. The teachers' role was primarily as observer, with some involvement in research practices over the two-week period. ICAN teachers also participated in ten, four-hour sessions focusing on NOS, scientific inquiry, and unified concepts through a series of explicit/reflective activities, readings, and discussions. The teachers' understanding of NOS was assessed with the Views of Nature of Science-C [VNOS-C] questionnaire (Lederman et al., 2002). Results continue to indicate considerable gains in NOS understanding of teachers involved in the ICAN program (Lederman & Lederman, 2005). The ICAN program involved teachers on the periphery of scientific inquiry with scientists, and the results are quite promising. A question remains, however, regarding NOS learning that might occur within a full immersion program whereby NOS is explicitly addressed.

Several years ago, we examined secondary science teachers' NOS perspectives resulting from a science research internship (Westerlund et al., 2001). This program, now referred to as "Trial A" of the Science/Math/Technology Education Institute (SMTEI), was an eight-week summer research experience in which secondary science teachers were full participants in research laboratories and mentored by research scientists full-time. Explicit NOS instruction was not provided in Trial A, but NOS learning outcomes were assessed as a test of the lingering question about the impact of a full immersion program on participants' NOS views (Schwartz et al., 2004). Pre and post assessments of NOS views were collected with the Views of Nature of Science-C [VNOS-C] questionnaire (Lederman et al., 2002). Results indicated the Trial A SMTEI participants demonstrated only slight gains in NOS understanding. A question emerged regarding how different the NOS learning outcomes would be within a full immersion program provided NOS were explicitly addressed. Trial B of the SMTEI included explicit NOS instruction. The purpose of this paper is to (1) compare NOS learning outcomes between Trial A (no explicit NOS) and Trial B (with explicit NOS) of the full-immersion SMTEI, and (2) describe changes in NOS views that occurred during the full immersion program with explicit NOS instruction.

Methods

Study Site: An Overview of the Summer Science Research Program

The SMTEI institute was a five-year National Science Foundation grant-funded 8-week summer research institute based at Texas State University –San Marcos. The institute refers to a summer program that provided scientific research experiences to approximately 20 secondary science school teachers. Teachers were placed in biology, chemistry or physics laboratories of scientists with whom their interests matched. Most of the scientists were biologists due to the larger size of the biology department. The SMTEI was housed within the biology department. The SMTEI web page provided a description of the research areas of the participating research scientists. During the online application process, teachers listed three scientists, in order of preference, in whose research they were interested. Prior to placement, teachers were interviewed by the SMTEI staff and the research scientists at the university to assist in the matching of teachers. The participating secondary school teachers varied in teaching experience, interests, age, and teaching positions. Each teacher received a $2900 stipend for participation, $1400 for classroom expenses, dormitory university housing, and two hours of graduate credit.

Nineteen teachers in Trial A and 21 teachers in Trial B participated in the program. The participants' demographics and prior teaching and research experiences in the two trials were similar (see Table 1). Teachers spent up to 40 hours per week in their respective research settings, designing and conducting individual research projects (see Table 2) with the guidance of practicing scientists. Generally, the teachers joined a research team with an investigation in progress. Thus, the hypothesizing and experimental/observational design steps had been completed to a certain extent. In the first week of the institute, the scientists assigned pertinent readings in the scientific literature for their partnered teachers. After discussing the readings with the teachers, the scientists allowed the teachers to "stake out" a portion of the overall project as their own. Teachers were also mentored by graduate students who were in the laboratories. The scientists and their research laboratories were housed in the biology, physics and chemistry departments. The SMTEI program was designed so that 95% of the teachers' time was spent conducting research. The long length of the program (eight weeks) allowed time for teacher participants to concentrate on their projects. Westerlund et al. (2002) evaluated the teachers' research experiences in the SMTEI program by comparing the SMTEI research experiences to the five authentic science AAAS features mentioned earlier (AAAS, 1989, p.26-27). Westerlund et al. (2002) found in the year previous to the present study, that 1) development of experimental or descriptive research designs, 2) the obtaining of evidence by "observations and measurements taken in situations that range from natural settings to contrived settings," and 3) the development of explanations based upon observations were all authentic science AAAS features present in the teachers' eight weeks of scientific research. Furthermore, the eight weeks of focused research time were characteristic of authentic science experiences as extended immersion experiences (Carlone & Bowen, 2003).

SMTEI participants were immersed in the research setting and culture particular to their project to the extent that they took ownership for their research questions and investigation development. Participants kept written journals, guided by questions intended to focus descriptions on the activities of the research settings. The teachers' research experiences during both trials of the program were similar (see Table 2). Also, for Trials A and B, the teachers met for two-hour group sessions every week to discuss their experiences with each other, the program faculty, and a scientist.

Table 1
Demographics of Teachers

Trial	# of males	# of females	0-1 Yrs Teaching	2-5 Yrs Teaching	5-10 Yrs Teaching	10-20 Yrs Teaching	# with prior Research Exper	# without prior Research Exper
Trial A	7	12	5	6	4	4	6	13
Trial B	9	12	4	11	4	2	9	12

Table 2
Sampling of Immersion Research Experiences in Trials A and B

Trial A Research Experiences	Trial B Research Experiences
Identification of the territorial range of the Spiny Crevice Lizard, tagged with RIT tags, dusted with fluorescent powder. Collection of fecal material of lizards to examine diet.(Albert)	Established a dichotomous key of digital pictures of kudu dung that demonstrates the diet of kudu. Developed microscopic photography techniques. Identified key factors in plant taxonomy such as cell walls, stomata, tricomes etc. Determined which photos to keep for the establishment of a new key of plants used in the kudu diet. (Eric)
Water quality assessments. Through chemical analysis, using QA/QC protocols, Bio-assessments, and identification of invertebrates as indicators of water quality. Conducted analysis on new site, Ben's stream in Kingwood, [close to her school], collected samples in Kingwood, and analyzed them at SWT. Used GPS equipment to identify discharge site. Collected water samples and conducted water tests. Flame absorbance for iron. Precision volume, dry weight measurements, preparation of mediums in autoclave, pH testing, water hardness, "wrist-flip" method, non-contamination techniques, E.coli tests, BioAssay lab, BOD[Biological Oxygen Demand], COD [Chemical Oxygen Demand], Ammonia testing. (Benelda)	Conducted aquatic bioassays in ponds. Observed algae in ponds, observed and took burette of water clarity, turbidity, phytoplankton bioassay, measured phosphorus and nitrate levels in spring and pond water. Utilized a hydrolab which automatically measured pH, temperature and dissolved oxygen. Used a Quantitative Enrichment Periphytometer to determine the limiting nutrient limit. Dispensed solutions in darkness. Learned how to use and calibrate the flurometer to measure chlorophyll concentrations of bioassay samples. Learned how to calculate chlorophyll A readings and how to determine alkalinity. (Riley)
Examined the fire retardant abilities of processed combinations of phenolics and clays for use in aircraft and submarines. Research question involved finding the right modulus (resistance to deformation, non-brittle and low peak heat release rate). Examined nanocomposites of polymers. Worked with twin-screw extruder. Calibrated ovens and cone calorimeters. Prepared phenoloic and siloxase plaques. Set temperatures of plaques for curing (Nan)	Combined various combinations of clay product with other substances to find a color improvement for the polymer. Conducted the research on the clay smectite, which has very distinctive properties such as being hydrophilic.. Combined the polymer (polylactic acid) to clay mixtures. Prepared plates of processed clay mixture materials (Justin)

Trial A Research Experiences	Trial B Research Experiences
Conducted a baseline study of resident (breeding) summer birds along the San Marcos River. Monitored six sites along the river. Made bird identification based on sight and sound. Also examined what fish eating birds are on the San Marcos River to see if they may be a disease vector in spreading the parasite, Piscivores, which may threaten the endangered fish, *Gambusia.* Monitoring of colonial nesting birds, isozyme analysis of Texas Madrone (Susan)	Conducted a bird census on the HEEP property, which is Blackland Prairie Habitat. Observed birds on the university campus and downtown. Used point count techniques. Examined bird behavior Determined a. nest sites, b. behavior birds of the same and different species, c. roaming territory, d. other behaviors. Concentrated studies along power lines since the nests were primarily found in this area. (Kevin)
Experiments with B-1 DRG cells and John's DRG cells. Grew on cultures of different glucose and manitol concentrations with different antibodies at 1 and 3-day time points. Grew B-4 DRG cells. Dissected rats to acquire sciatic nerves. Prepared media for growing nerve cells (Schwann cells). Retrieved DRGs from spinal cords from rat pups. Acquired collagen from rat's tail which provides a foundation for nerve cells to attach and grow. Collagen coat cover slips for the use of DRG cultures. (Karen)	Studied complications of diabetes called diabetic neuropathy. Examined Schwann cells in terms of age modification in hyperglycemia media. Conducted dissections of sciatic nerve and spinal cords in P2 rat pups to obtain Schwann cells. Utilized techniques such as running protein gels and electrophoresis. (Dan)
Examined overstory and understory interactions of woody plant species to explore the interactive effects of competition and facilitation on woody patch development and persistence. Became familiar with techniques and methodology fundamental to plant ecology. Measured leaf areas with a leaf area meter. Measured/calibrate leaf area computer programs. Measured leaf areas with a scanner/computer, and compared findings with the leaf area meter. Measured stomatal conductance, chlorophyll fluorescence, and photosynthetic rates. Took water potential readings. (Evan)	Established plots and analyzed the competition between native and exotic plants. Measured plots 1 $m^{2..}$ Removed Colecasia eseulenta (Elephant Ears -exotic species) from random sampling plots. Planted Zigonoporis milaceana (Giant cut grass) in random and P plots and measured heights. Marked them with flags. Conducted soil analyses. Removed hyacinths (exotics) in other areas. Conducted 50-meter line transects. (Blair).

Trial A Research Experiences	Trial B Research Experiences
Tracked 16 deer that have already been radio collared to determine movement patterns in Mason, TX. Conducted radio telemetry. Took vegetation samples. (Opal)	Studied pond ecosystems involving hydrilla, grass carp, and Texas shiner fish. Collected samples from various lakes. Dissected and analyzed the sub content of specimens. Devised hypotheses of the schooling behavior of fish from the data collected. Evaluated the success of fish habitats in enclosures in regards to Texas Shiner fish and small mouth Bass through fish collection at timed intervals. Mended nets to use in the collection of fish in the raceways. Assessed pond depths using a boat. (Pat)
Research involved trying to remove organosulfates from crude oil using bioremediation techniques. Fractionated crude oil samples using column chromatography into different classes of compounds. Prepared samples for the aromatics fraction of the Nuclear Magnetic Resonance (NMR), High Performance Liquid Chromatography (HPLC), and LCQ. (Frank)	Dissection of the earthworm to examine nephridia, Used the Reichert Ultracut, SEM electron microscope. Stained relevant sections of the earthworm. Developed pictures from the transmission electron microscope (TEM). Examined TEM grids to examine nephriidia sections. (Meg)

Difference between Trial A and Trial B Summer Science Research Programs

Trial A and Trial B summer programs were exactly the same except for the inclusion of explicit NOS instruction during the weekly two hour sessions of Trial B. Both programs met every Monday afternoon for 8 weeks. During these meetings, business items, their laboratory experiences and classroom lesson plans were discussed. All participating teachers, SMTEI program faculty, including one or two scientists, and a science educator were present at the meetings. During the meeting the Trial A participants were not provided with NOS instruction, with the exception of two spontaneous discussions concerning the differences between scientific theories and laws, and creativity in science.

Description of the NOS instruction

Trial B participants met for the two-hour group session each week to discuss their experiences with each other, the program faculty, and a scientist. It was during these sessions that NOS was introduced. NOS activities were similar to those of Lederman et al. (2001) and Lederman et al. (2002), some of which are detailed by Lederman & Abd-El-Khalick (1998). Other lessons included a black-box Earth model activity (Schwartz, Lederman, & Smith, 1999), a "mystery bones" creature reconstruction (J. Lederman, personal communication, 2000), a southwest cactus inquiry, and NOS concept mapping. The NOS explicit lessons were videotaped. The videotaped lessons were analyzed at a later time by the first author, an experienced NOS researcher/teacher. The first author viewed only the videotapes and was not present at the meetings. All of the eight targeted NOS tenets were presented at some time during these lessons. Representative lesson excerpts are presented in the Appendix. These excerpts represent the type of explicit NOS instruction during the sessions. Explicit NOS instruction is bolded in the excerpts. Overall, NOS was explicit through direct instruction, with some opportunity for reflection. Participants kept written journals, guided by questions intended to focus descriptions on the activities of the research settings. Activities were designed to include discussion, and several incorporated journal writings to promote the participants' abilities to associate their NOS views with their research experiences. Participants also read and discussed articles about NOS perspectives (Lederman et al., 2002) and common myths about science (McComas, 1998).

Data Collection and Analysis

For both trials involved in this study, the Views of Nature of Science questionnaire [VNOS-C] (Lederman et al., 2002) was administered to the teachers in a pre-test and post-test format. The VNOS-C is a 10 item open-ended questionnaire that assesses respondents' understanding of the targeted aspects of NOS (tentative, subjective/theory-laden, creative, empirical, social/cultural embeddedness; distinction between theory and law; distinction between observation and inference). Additionally, ideas about "a single Scientific Method" often emerge from VNOS-C responses, thus allowing for descriptive details of participants' views of eight aspects of science. Based on recommendations by Lederman et al. (2002), the second author interviewed 30% of the teachers, pre and post. The interviews were guided by the participant's VNOS responses. The purpose of the interviews was to establish validity of researcher interpretation of written responses, as well as to further probe respondents for clarification and expansion of ideas.

To establish inter-rater reliability, the first and second authors conducted independent analyses of the pre- and post- tests and interviews. Analysis focused on describing participants' views and identifying areas of change. Responses were considered, compared and contrasted for an overall representation of a position relative to the targeted NOS aspects. Responses were reviewed for consistent and inconsistent statements, examples, and extent of elaboration beyond simple description. Responses were classified according to a NOS views continuum of "naïve" to "more informed" perspectives (Figure 1; Schwartz, 2007). The continuum represents a range of types of views individuals display from naïve to informed to quite sophisticated (more informed). We acknowledge that participants' views may shift in either direction. The continuum enables representation of views so that comparisons can be made among participants' in a given study. Distinctions can be made between two responses that both may represent an informed view, but one may clearly present a more sophisticated level of understanding than the other. Classifying responses on a dichotomous naïve/informed system does not allow distinction between levels of sophistication or enable identification of changes other than from naïve to informed (or informed to naïve). Identifying more subtle shifts can be helpful to better understand the impact of an intervention. The symbols beneath the continuum enable transference of analysis results from the continuum to discreet categories. Such results are then represented in tabular form for summary and comparison purposes. The results section contains tables based on this transference.

Naïve>>>>>(emerging)>>>Informed>>>>>>>>>>>>>>>>>>>>More Informed

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Figure 1. NOS views continuum

Statements representing naïve views portray science contrary to the aforementioned accepted perspectives. For example, a naïve view of the tentative NOS implies that knowledge can be obtained that will never be subject to revision. But, even apparently dogmatic scientific concepts such as a round Earth with a consistent gravitational field can be subject to revision as indicated in studies by the joint NASA-German Aerospace Center Gravity Recovery and Climate Experiment (GRACE) mission. Within a naïve perspective, scientific knowledge is viewed as objective and culture-free, revealed by the data alone; whereas a more informed view would describe scientific knowledge as determined through inferential and creative activities that find meaning within data to support conclusions. For the analysis, degrees of understanding were based on respondents' use of examples, elaboration of statements, and demonstrated connections among NOS aspects and science contexts (Lederman et al., 2002; Schwartz et al., 2004). Deeper understandings, evidenced by elaborations and explicated connections to contexts, are placed somewhere along the "informed" side of the continuum. Differences between "informed" and "more informed" are determined by the sophistication of responses. Those responses that demonstrate an informed view but elaborate on the aspect and/or provide supporting examples are considered to be "more informed" and are placed along the right side of the continuum depending on the extent of elaboration. Emerging views are those not completely consistent with an informed perspective, but also not completely naïve. These views may be in transition, or fluctuate, between naïve and informed. Such responses often exhibit inconsistencies or inappropriate supporting examples, which reflect confusion or fluidity in the process of formalizing views.

For both trials of the study, the two collaborating researchers compared their independent analyses for each teacher and discussed profiles until 100% agreement was obtained. Changes in NOS conceptions were identified by comparison of the pre and post-research experience profiles.

During Trial B, the weekly sessions were videotaped and explored for instructional attention and dialogue relative to NOS and research experiences. To minimize researcher bias, only the researcher not directly involved in the program conducted this analysis, and only after completion of the questionnaire and interview analyses. Videotape analysis described NOS instruction, identified explicit episodes, and identified opportunities conducive for NOS instruction. These results are mentioned here for explanatory purposes related to the research questions.

Results

Comparison of Trial A and Trial B Programs

A comparison of NOS learning outcomes of the program with (Trial B) and without (Trial A) explicit NOS instruction is presented in Table 3. Trial A resulted in little change in participants' NOS views. The 21% change with respect to views of creativity corresponds to the spontaneous discussion about the use of creativity and imagination in science. This and another discussion about differences in theories and laws were the only two instances of NOS discussion during Trial A. Both were unplanned. Both were initiated by the participants.

By comparison, the Trial B participants demonstrated greater improvements in understanding of NOS (16% informed in 4 or more aspects in Trial A vs. nearly 74% informed in 4 or more aspects in Trial B). The largest differences in effects on views between the two trials occurred in areas of theory/law, creativity, tentativeness, subjectivity, and observation/inference. Because the two trials were similar in all respects except the NOS instruction, the difference in NOS learning between the trials may be attributed to the methods of explicit NOS instruction employed during Trial B.

Table 3
Comparison of Percent Change in NOS Understanding in Trials A and B

	Trial A			Trial B		
	Pre *NOS* Views	**Post *NOS* Views**	***Trial A (no NOS)***	**Pre *NOS* views**	**Post *NOS* views**	***Trial B (with NOS)***
***NOS* aspect**	**% informed**	**% informed**	**% change**	**% informed**	**% informed**	**% change**
Scientific method	NA	NA	NA	19%	67%	48%
Creative	11%	32%	21%	19%	57%	38%
Tentative	6%	16%	10%	35%	*65%	30%
Theory/law	0%	10%	10%	9 %	38%	29%
Obs/inference	42%	42%	0%	20%	45%	25%
Subjective	21%	26%	5%	43%	**67%	24%
Empirical	79%	79%	0%	84%	100%	16%
Socio/cultural	16%	16%	0%	38%	48%	10%

Trial A: full immersion research; no *NOS* instruction

Trial B: full immersion research; explicit *NOS* instruction

- % informed represent those participants with views classified on the "+" side of the NOS views continuum. Thus degree of understanding varies among the "informed" participants.
- % change represents the percentage gained from pre to post in informed views.
- *Shifts were primarily related to recognition of change due to new observations or advances in technology. One of the participants demonstrated change due to reinterpretation of existing data from a different perspective. The latter view is representative of a deeper understanding of tentativeness. Thus the "informed view" represented by these participants in the post-test is relatively shallow, yet an advance, nonetheless.

The difference in outcomes between Trial A and Trial B is encouraging, and somewhat predictable given prior research results. The significance of these results lies with the nature of the changes. We focus the remainder of the results presentation on describing the changes in NOS views observed in Trial B. These descriptions portray nuances of change and offer insights into contextual features of the program that may have influenced the changes. The quotations included are representative of participant responses.

Trial B: Changes in NOS Views

Table 3 presents the group profile and changes in views for each NOS aspect. Overall, participants from Trial B held pre-internship views within the naïve range. When comparing the number of participants with informed views in the pretest to those in the posttest, we can determine areas of change. The largest degree of change for Trial B teachers concerned the recognition of multiple methods of scientific investigations and the role of creativity in science. We observed 48% and 38% gains, respectively. The least change occurred in areas of empirical basis of science and the socio/cultural embeddedness of science, which were 16% and 10%, respectively. However, as will be discussed, reasons for the relative low gains for these two aspects differ.

Table 4 presents final NOS views and characterizes observed changes for each Trial B participant. The teachers are listed in order from most change (Tony) to least change (Ben). These names of program participants and scientists are pseudonyms. The "M" in the NOS aspect column indicates a major change from a pre-test naïve view to a post-test informed view on the continuum (Figure 1). For example, Tony demonstrated a major change in his conception of the tentative NOS. On the pretest, he displayed a naïve view that was coded on the left side of the continuum. On the posttest, his responses indicated a major improvement from the naïve view to an informed view that was coded in the "+" region. This is considered a major change [M], from naïve to informed. Lesser changes are also identifiable on the continuum. For individuals who shifted in the desired direction, but not completely from naïve to informed, were considered to have "changed" [C]. Kevin provides such an example. His view of the subjective NOS began as naïve and shifted in the positive direction, but he still maintained some inconsistent notions about the aspect. He was coded as "-" initially, and placed in the "(+)" range for the posttest. Thus, we consider his change to be in the desired direction but not a major change. Participants who began the study with somewhat informed views and developed more sophistication of those informed views were also considered to have changed in the desired direction [C]. Natalie provides an example of such a change with respect to her view of observation and inference. Initially, she held informed views that affirmed the distinction between observation and inference. Thus she was placed in the "+" range. For the posttest, she was able to provide more examples and explain the distinction between observation and inference through those examples. We considered her posttest views more sophisticated than her pretest views, though both still informed. Thus, she demonstrated a positive shift along the continuum [C].

Post-internship, 16 of the 21 participants (76%) held more informed views for four or more NOS aspects. There is no apparent correlation between research area, background, or teaching experience and NOS conceptions or changes. Here we discuss results relative to each targeted NOS aspect for Trial B.

Table 4
Trial B Participants' Final NOS Views and Changes in Views

Teacher	**Tentative**	**Subj**	**Emp**	**Creat**	**Soc/cult**	**Theory/law**	**Obs/inf**	**Sci.Meth**
Tony	+ M	+ M	++ C	++ M	++ M	++ C	+ M	++ M
Morgan	+ M	+ M	+ M	-	-	+ M	+M	-
Blair	+ M	++ M	+ M	+	+	+ M	(+)	++
Nick	+(+)	+	++ C	+	(+)	++ M	++ M	+ M
Kevin	+ M	(+) C	+	+ M	+	(+) C	-	+ M
Jane	+	(+)	+	+	(+)	+ M	+ M	+ M
Dan	+ M	+ M	NA	(+)	+ M	-	(+)	-
Riley	+ \ - C	-	+	+ M	(+) C	(+) C	-	++ M
Justin	+/ -	(+) C	+	+ M	++ C	-	(+)	+ M
Meg	+	+	+	+ M	(+)	-	(+)	++M
Pat	(+)	+	+	+ M	+	+ M	++	-
Robyn	+ M	+ M	+	+	+/-	-	(+)	-
Natalie	(+) C	++ C	+	(+)	(+)	(+) C	++ C	+ M
Chad	(+) C	+	+	+ M	(+)	-	+	-
Audry	+	+	+	(+) C	+	++	+ M	+
Joy	+-	+	+	(+)	+	(+) C	-	+ M
Eric	+	+	+	-	(+)	+ M	-	-
Anna	+	-	NA	(+)	+	-	-	+ M
Callie	+	+	+	+ C	+	-	_	+
Jill	+/-	-	+	-	-	-	+	+
Ben	NA	-	NA	-	-	-	NA	-
% with any "+" shift ('M' or 'C')	45%	38%	21%	43%	19%	52%	30%	48%
# participants with major "M" shift/ # participants with initial "-" view	6/11 (55%)	5/13 (38%)	2/2 (100%)	7/13 (54%)	2/7 (29%)	6/19 (31%)	4/11 (36%)	10/17 (59%)

M: major change from naïve "-" to more informed "+" view of *NOS* aspect.

C: Change in positive direction on continuum (toward more informed view of aspect). Initial view may have been on "+" or "-" side. Response on post-test represented a view developing in the desired direction. Resultant view was enhanced "++" or "+++" or emerging "(+)".

NA: not available based on responses. These were not factored into the calculation of percentages.

Multiple Scientific Methods

Only 19% of the participants initially recognized that scientific knowledge could be developed through non-experimental methods. Less informed (naïve) views portrayed an experimental method as the only valid method of scientific investigation. Sixty-seven percent of the participants at the end of the 8-week program held the view that scientific knowledge is developed through methods of experimentation as well as through descriptive and observational techniques. This area represented the most change overall for the NOS aspects targeted, with 10 of the 17 initially naïve views advancing within the informed range (Table 4). The following quotes from Riley represent a shift in pre to post views of scientific methods:

Riley pre-test: A science experiment is the execution of the scientific method to perform a test to answer a science problem…The development of scientific knowledge does require experiments…Experiments offer students the opportunity to prove scientific outcomes rather than just having to accept as fact something that was read in a book.

Riley post-test: An experiment is the process of conducting a planned activity to test a hypothesis. In my research we conducted experiments by performing bioassays to determine the limiting nutrient of algae…Scientific knowledge can be gained by other methods such as making observations and collecting data. In my limnology research, we developed scientific knowledge by collecting data from the lake during a period of heavy rain. This was not an experiment but the data collected illustrated distinct patterns in terms of how conductivity and dissolved oxygen were affected by the rain.

Riley post-interview: Initially, I thought we just have to do experiments. Now there are other things that we could do other than just experiments. Just making observations and collecting data, drawing inferences and conclusions. Initially, I thought that was the only way to find out valuable information, if you conducted experiments…It doesn't have to be the scientific method all the way through. In the beginning, I thought that it had to be.

Creativity and Imagination

The second greatest area of change occurred relative to understanding scientists' utilization of creativity and imagination. There was a change from 19% to 58% (pre to post) of participants holding a more informed view that all areas of investigation, including analysis and interpretation, involve, or even require, creativity.

Limiting creativity to design was the typical naive response. Some delineated boundaries of creativity within science. For example, Ben stated, "Creativity and imagination play a part in devising the investigation but not in trying to find answers to the questions." In this case, creativity was equated with resourcefulness, necessary to solve problems or invent methods. Natalie provides another example of this position:

Natalie Post-test: Observing my calorimeter experiments, I had to make sure the conditions were kept the same for each specimen but I had to annotate any modifications I made such as moving the igniter over a bit due to swelling of the polymer. I helped modify our analysis sheets. I figured out the linear slope of the graph to better display actual combustion….Our lab manager makes things work through creativity and imagination.

Creativity was seen as unnecessary post-data collection because answers were revealed by the data alone. This is a "seeing is knowing" view, indicating that data reveal the answer by simple fact of being visible. This view fall within the naïve range because it lacks recognition of creativity and imagination in negotiating meaning from data.

The nine teachers who advanced in understanding the creative NOS acknowledge the use of creativity and imagination in data analysis and interpretation to develop meaning from data and draw conclusions. Some participants attempted to provide examples from their research experiences to explain their views or changes in their views of creativity:

Riley post-test: Scientists use creativity in all stages…Creativity is often needed in planning and designing an experiment. Creativity is needed after data collection to make interesting connections or develop ideas for new experiments that expand or extend from the first one…

Riley recognizes that creativity is involved in "making interesting connections" from data. When probed further in the interview, he mentioned this role again, but did not elaborate or provide examples from his research.

Riley post-interview:

Interviewer: What made you change your view concerning creativity….in your work this summer?

Riley : I would say so. And the discussions that we have had. When essentially we got here, we had a little background on limnology, but all of our experiments we had to come up with. Everything from beginning to end. We did materials, we did design and then evaluating it. It took creativity through every step, not just the design, everything, thinking about what are we doing and why are we doing it. It wasn't cut and dried. It definitely required creativity.

Overall, final views of creativity were within the lower range of informed on the NOS views continuum, such as Riley. That is, the participants who had a "+" view of the creative NOS tended to reiterate that scientists use creativity in all stages of scientific investigations. Only Tony was able to provide appropriate examples to support his statements. This result suggests that the participants did not clearly connect their data analysis experience with their views of the creative NOS. The current study does not have sufficient information about individual participant's roles in data analysis and interpretation decision-making to draw further conclusions.

Tentativeness

At the end of the Trial B summer institute, there were 30% more participants who recognized the tentativeness of scientific knowledge (35% pre compared to 65% post). Those in the naïve range saw science as immutably fixed according to what is presented in textbooks or information changing due to additions, rather than changes in what has already been published. Kevin stated on his pre-test, "I hope they are very certain on the structure of the atom because I have been teaching this for 7 years now." Those in the "informed" range tended to affirm that science can and does change or that scientists are never 100% certain. Most were unable to provide a rationale for change, and were designated as "+" on the NOS views continuum. Those who indicated change due only to new observations were also designated as "+" because new observations only partly explain why scientific knowledge changes. After the SMTEI, Kevin fell into the "+" range because he recognized that change happens, but didn't provide reasons for change:

Kevin post-test Neither are absolute but a law is more concrete than a theory. Both are apt to change over time. I don't think scientists can ever be 100% sure about any type of thing. I would not be surprised if a different scientist proposed a different model. [Examples of change: Kingdoms]

None of the participants provided appropriate examples from their research settings or elsewhere to represent change beyond simple changes that were encompassed in the investigative design. Broader impacts of change on investigative framework, research agenda, or research discipline were not discussed. Despite the positive advance and encouraging numbers, the reasons stated for the tentativeness of scientific knowledge indicate that most participants were relatively unsophisticated in their understandings of the inherent tentativeness of science. They did not grasp the relationship between knowledge development and perspective, where if data are examined in a different way, through a different theoretical or cultural lens, then the knowledge may also be different. This level of sophistication was not evident among this sample.

Scientific Theory and Scientific Law

Hierarchical views. At the beginning of the program, 91% of the participants held the common hierarchical view that scientific theories develop into laws. Within this perspective, scientific theories are considered ideas or guesses to be tried out and tested through experimentation. Theories also are believed to be tenuous because they lack data. After rounds of investigations and accumulation of data, the theory is "proven" and granted status of "law," not to be questioned because "you know a law will always happen." The following are examples of statements consistent with this "naïve" view, and thus were placed on the naive side of the continuum:

Ben pre-test: A scientific theory is based on unfounded suppositions and has flaws and contradictions. A scientific law is well represented by solid facts.

Riley pre-interview: I just think a theory offers a probable explanation for some science concepts but is not necessarily the whole truth and nothing but the truth. It still has yet to be a 100% proven fact; whereas a law is correct and accurate. So I think a theory wants to be a law but it is not quite there yet, or something has to be discovered to prove that it is a law.

Limited advances. Thirty-eight percent of the participants voiced a more informed view of the distinction between theory and law on the post-test VNOS, for a 29% positive change from pre to post. Nick demonstrated more dramatic change because of his post-test inclusion of appropriate examples:

Nick pre-test: A scientific law differs from a theory in the fact that a law is measurable, proven concept that is the same every time…A theory is something that has been researched but is still not proven beyond a doubt. It may be that there is missing information, or that our technology hasn't allowed us to measure it yet…For some reason the concept hasn't been proven.

Nick post-test: Scientific theories and scientific laws are two very different types of knowledge. You could say that theories explain "why" something happens while a law states "what" is happening. Theories try to explain why natural phenomena occur using observation and collected data. Ex: evolution occurs due to random mutations that allow an organism to fit into its environment better. A lot of facts and data support this theory. A law tells us what is happening in a natural system. Ex: gravity pulls objects toward the earth at 9.8 m/s2. This doesn't explain why, only what happens.

Despite the encouraging gains, Nick was an exception to the type of advances that were typical of the group. Those who demonstrated change tended to reiterate descriptions from class readings with little elaboration. None provided examples from their research settings to support their views. Nonetheless, advances were evident.

Inconsistencies. Four participants who initially held hierarchical views of theories and laws demonstrated shifts in the informed direction, yet maintained inconsistencies. For example, Jill initially saw theories and laws as similar. After the program, she saw them as qualitatively different. Despite her distinction, she still held naïve notions about scientific laws and was unable to give up her view that laws are unchangeable:

Jill pre-test: A scientific theory is where an experiment about a proposed hypothesis has been carried out so many times …where the results are always the same. At this point the "theory" might be considered a "fact" in some scientific communities. Therefore suggesting that "scientific theory" and "scientific law" would be the same.

Jill post-test: In a scientific theory, there is qualitative data to support its statement. However, as technology and data changes, the theory can change. A scientific law can be explained in a quantitative form. The equation will never change even with the invention of new devises and the submission of new data.

She changed her conceptions of theories and laws, now seeing them as different in types of encompassing data. Yet laws are considered mathematical entities that are unchanging, regardless of technological advances.

Observation and Inference

There was a positive shift in 25% of the participants regarding the distinction between observation and inference. Recognizing the role of inference in science involves relinquishing the requirement for knowledge to be based on direct evidence only. Inference utilizes available data, direct or indirect, to explain unobservable phenomena. A response affirming this position is evident in Tony's post-test, "Scientists use indirect evidence and creativity to model the atom. It is not an exact replica." This response is in contrast to Joy's post-test that said, "Science uses direct observation or conceived models (based on everything that is known at the time about that thing) to explain or visualize some of its concepts. Science is NOT based on inferences." Joy demonstrates a more uninformed view that emphasizes observations alone contribute to valid scientific knowledge.

A few related the summer research activities to views of observation and inference. Natalie presents a clear role and rationale of inference in the research she conducted.

Natalie post-test: Of course an atom is not something a scientist can pick up when needed. Much is done by inference. She sees the results of atoms and then she modifies the environment, she observes the changes. I believe scientists can be very competent in their determination of what an atom looks like via their inference. When I caused a polymer to combust, I could not see the gas atoms burn, but because the material changes its physical form when [different temperature] was applied, I inferred the gas vapors were leaving the material. Eventually all that was left was char. The solid material changed its form or its atomic structure right before my eyes. It was amazing to see it happen once I was exposed to the atomic theory and saw it in action. So I'm sure scientists use similar experiments to observe behavior of physical structures as they change from one form to another.… When I burn a specimen and see it turn to charcoal, that is observation. What actually occurs is inference.

Subjectivity and Theory-ladenness

Initially 67% saw science as primarily objective, based on value-free collection and analysis of data:

Tony pre-test: Science is a discipline that depends on gathering evidence through the use of observations. This data is collected in a way that is nonbiased…This method of inquiry is largely different from other disciplines in that the approach is objective and data collected is quantifiable. Disciplines such as religion and philosophy are subjective and not based on quantifiable observations.

Other typically naïve views were that scientists disagree about scientific explanations simply because they lack data, rather than they hold different theoretical frameworks within which the same data may be interpreted. Anna suggested that different explanations for the dinosaur extinction result from a lack of data. She thought the controversy could be resolved quite simply: "More proof is needed," and "It is the data that is not available that creates this diversity of opinion." These statements are consistent with a view of "seeing is knowing," or suggest that the answer is revealed objectively through amassing sufficient data. Such a view does not necessarily connect a theoretical framework with finding meaning from data.

In Trial B, the primary shifts were from seeing science as objective to recognizing the influence of personal subjectivity in investigating questions and interpreting data. This view is more informed than the "objective" position, and is classified within the emergent range of the NOS views continuum:

Justin post-test: One major problem we face and will always face is that a set of facts may mean one thing to someone and something totally different to someone else. Hard facts and data will always be open to interpretation.

Blair explained a slightly more informed view by including the influence of a mindset and an example from her summer research:

Blair post-test: Scientists bring more than just facts and figures to their scientific work. These factors (interpretation, mindset, personal and professional knowledge & experience) all consciously and unconsciously impact their interpretations and the degree of value placed on certain data [emphasis added]. For example, Robyn and I worked very closely together on our projects, using many of the same literature and resources and similar plot sites. Yet the way we express our results in our posters will differ somewhat.

Because she talks about professional knowledge and mindset, this statement suggests a more sophisticated view than personal subjectivity. However, the closing remark about expressing results may be reemphasizing personal preference rather than influences of deeper theory-laden judgments in data interpretation and argumentation.

Of those who affirmed an influence of subjectivity, all recognized the role of personal subjectivity. Some respondents had a negative reaction, equating subjectivity with manipulation or cheating. Also, we identified shifts from an "objective" view to an "everyone has their opinions" view. This shift falls short of the more sophisticated perspective that values theory as a framework for scientific investigations and interpretation.

Empirical

From the beginning of the program, most participants perceived that scientific knowledge is grounded in empirical data. The entire sample (100%) demonstrated some understanding of the empirical basis for scientific knowledge at the completion of the program. Thus the low gains for this aspect reported in Table 3 is simply due to the large initial numbers. Statements representing informed views included distinguishing science from other ways of knowing:

Audry posttest: Science is the discovery of knowledge of the natural world through observation and/or experimentation/modeling. It is different than philosophy or religion because, for example, philosophy is opinion, religion is dogma, and science seeks through evidence to understand and gain knowledge. Religion doesn't require evidence, just FAITH.

Nick was able to present an example from his summer research to support his view:

Nick posttest: Science provides data to be interpreted. I studied ground water quality in aquifer wells. Some have bad water quality while others have good water quality. Scientific research says that the dissolved minerals in the water from the underground rock formations affects water quality. Religions or philosophies may explain bad water areas as "cursed" or something to this effect.

Sociocultural Embeddedness

Only 10% of the participants demonstrated a positive change in their conceptions of the socio/cultural embeddedness of science, with 48% of the participants holding somewhat informed views by the end of Trial B. Typically naïve views consider science "universal" and void of influences outside the individual scientist. This view does not take into consideration the societal or cultural influences on how scientists approach scientific problems, what scientific questions they choose to explore, how data may be interpreted within the social and cultural perspectives, and how the knowledge may or may not be accepted. An interesting finding was the consistency of naïve views across the aspects of sociocultural embeddedness, subjectivity, creativity, and tentativeness in science, especially on the pretest. For example, Riley considered science to be universal because he considers scientific knowledge to be truth:

Riley pre-test: …scientific truth overcomes the social and cultural values because those values change and scientific truth does not.

Similarly, Tony connected the universality of science to objectivity and truth:

Tony pre-test: I believe science is universal due to the fact that it is an objective endeavor that produces data/evidence that can be proven in its purest form. It is not to say that science is not infused with social and cultural values – this science, however, would not be true/pure science. Any science that is biased is thrown out based on this bias.

Emergent views (+) were related to recognizing influences of political, economical, and ethical issues on what scientists investigate.

Meg pre-interview: I feel that social and cultural values do influence science…It really depends on the social and culture of the area, what monies are utilized for the funding and the research. For example, let's take AIDS in the early 80s; you saw money being pumped into that area of research, also cancer. The monies and also the persons that are in political power at that time directly affect that research…

Some of the emergent views were attributed to the summer research experiences. Whereas Riley, quoted above, initially saw science as void of societal influences, he revealed a different view after his research experience:

Riley post-test: I believe science reflects social and cultural values. Conducting scientific research is expensive. I feel that most research is being conducted based largely in part to what companies and government will pay for in terms of grant money. In my summer research, I felt that the experiments we performed were based on the grant requirements of my professor.

Tony came to recognize the social and cultural influences on how science is practiced. That is, the practice of science itself and identification, interpretation and acceptance of evidence varies based upon the culture in which the science is practiced. Recognition of influences on how science is practiced is considered a more sophisticated understanding than limiting influences to the what. Tony included an example that represents his idea that as cultural or societal conditions change, the perspectives of scientists also change:

Tony post-test: Science does reflect the social and cultural values because it is a human enterprise. Everybody is conditioned by the environment and systems that they are a product of. An example of this again from the reading is the interpretation of the evolution of humans – the predominant male scientist perspective – man the hunter. Then as more female scientists studied the human evolution, the perspective became one as a gatherer.

Videotape Analysis of NOS Lessons

The results of the videotape analysis (Excerpts of transcripts provided in the Appendix) suggest all the aspects of NOS were addressed during the group sessions. The participants engaged in several activities designed to introduce NOS. Based on the videotapes of seminars, the discussions in the Trial B program held mainly to the activities, with slight expansions to aid in connecting the research experiences. The instruction was primarily didactic. There were few guided/reflective questions in comparison to direct statements about NOS. The participants took notes and read handouts. In one assignment they were asked to connect their research experiences to the NOS reading, but the participants had difficulty recognizing appropriate connections and identifying explicit episodes from their research experiences.

In this study, many of the teachers raised concerns about NOS issues and their own classroom practice. It was during these dialogues that inconsistent statements or confusions about NOS were often raised. For example, the following is an excerpt from "the tube" activity. The italicized statements are suggestions for additional instruction.

Day 2

Tube. (Lederman & Abd-El-Khalick, 1998)
S (*teacher participants)* made own tube models.
Debrief: Had groups test models against original. Then explain model design.

[Need to reinforce making and testing predictions]

S: Shouldn't matter how the strings are connected as long as they are connected in the center.

[*T (program faculty) could have asked what they might want to do to gain further knowledge about how the strings might be connected.*]

Some students had changes with their design depending on where they placed their loop and the length of their strings.

[This would have been an opportunity to talk about reasons for CHANGE in models.]

After seeing several model demonstrations,
T: which is the closest model to the real thing?
S: either of the first two.
T: Until we can keep improving our models…
S: [says something about design…]
T: So we are talking about the tension…

Student gives additional evidence for why he thinks there are two strings and what holes have the strings.

[*This would have been a good chance to reinforce need to connect inferences with observations. Are his conclusions valid based on the evidence? Are the other models still valid? Why or why not? How do changes in model acceptance come about in science?]*

[Veronica did the tube activity with her seniors last year. She had some comments:]

Veronica: One problem with biology class was they wanted the answer. The little tubes were frustrating. Oatmeal containers are bigger and less frustrating. Helps illustrate the point of how science works on laws. Kids automatically think their idea is wrong. Lets say you came up with a model that isn't quite right. It is very valid. You didn't waste your time. You found out something important. You found out what isn't right.

S: Do you show them the right answer?
Vicky: I showed them a diagram.
T: Would you all show them?
S: No I wouldn't ever show them. It would frustrate them.
Veronica: But if science frustrates the heck out of them they will quit.

S: I think you show them the answer particularly if you have a kid who solved it in another way. You know, tell them this is what I did. If you don't cut it open and you have a kid who really wants to know the right answer. There is a right way sometimes. There may be more than one way.

T: And that shows how models can look like it is right but in reality it might not be.

[Needed to clarify what models are and the importance of the empirical NOS , connecting inference with observation, and that science does not accept "anything goes." A good model is consistent with the evidence, explains existing observations, and makes valid predictions. More than one model may do these. They may not be equally valid because some models may explain more data or serve to make more accurate predictions. Models are based on the available information and are consistent with current scientific understanding.]

None of these suggested discussions were on the activity lesson plan, and these opportunities to clarify NOS issues with teachers' own examples, even classroom connections, were not addressed. Nonetheless, the teachers' connecting the activity to their classroom is an important consideration. The teachers were aware that there was more than one possible solution to the tube inquiry, and that students can gain knowledge from making inferences and attempting to build and test their own models. Thus, there was success. Additional instructional steps could have been taken to further enhance the lesson and to challenge learners' conceptions, as suggested in the italics

Discussion

Changes in Nature of Science Views

Comparing outcomes from Trial A and Trial B reinforces the need for explicit NOS instruction, even in the context of a full immersion scientific research program. The changes in NOS views correspond with NOS instructional attention. Despite the full immersion research experiences of teachers in both groups, only those who were challenged to think about NOS aspects and make connections with their research experiences showed improvement. The authentic context of the research experience was insufficient to effect substantial change in participants' NOS views. Results for these teachers are similar to results reported for high school students involved in a summer research program (Bell et al.,2003).

In Trial A, there was little NOS instruction and little change in NOS views. There was unplanned discussion about theory/law and creativity, and a few of the Trial A teachers demonstrated enhanced views of these aspects. Trial B teachers demonstrated greater advancements that correlate with the broader NOS instruction. The NOS instruction in Trial B held mainly to the activities, with slight expansions to aid in connecting the research experiences. The explicit instruction was primarily direct, with the instructor emphasizing descriptions of the targeted NOS aspects and then attempting to connect the aspects to the seminar activities. Overall, the results from this study demonstrate that Trial B summer institute was successful in impacting participants' NOS views.

In Trial B, the teachers had a few opportunities to debrief the activities and their research experiences but they were not fully able to establish explicit connections to NOS on their own. They needed frequent guided opportunities to discuss, compare, and formalize their views in relation to examples (Schwartz et al., 2004). Otherwise they will, as seen in the results, reiterate the definitions or statements as provided to them. It seems the explicit/direct approach was effective in aiding these teachers developing enhanced NOS conceptions, but the instruction was limited in reflective/peer sharing opportunities that could have facilitated participants' connecting NOS issues with research experiences or other science content. Reflection opportunities are important to aid learners in connecting ideas of NOS to real activities of science (Schwartz & Crawford, 2004; Schwartz et al., 2004). Scaffolding through guided questions and modeling effective reflection (what is expected in response to the journal questions?) helps learners engage in meaningful reflection and discussion about their research experiences and notable NOS images within those settings to advance their conceptions.

In Trial B, the aspect of multiple methods of science received the most instructional attention. It was first introduced by asking the participants to consider their research areas and the investigative methods they were following. Then several class activities engaged participants in different types of investigations, many of which were descriptive (e.g. mystery bag and mystery bones). These experiences enabled participants to compare and contrast different ways of conducting scientific investigations. In reflection of their own research, participants were asked to describe their research methods and determine the extent to which they followed an experimental or a non-experimental approach. An experimental approach involves identification and control of variables and manipulation of at least one variable to determine cause/effect relationships. Non-experimental approaches involve descriptive studies that examine the natural state of a phenomenon through observation and/or identification of correlations among features of the phenomenon. This latter approach is more aligned with the mystery bag and mystery bone exercises. Attention to multiple methods was revisited throughout the program when participants would share updates on their research. They were consistently asked to compare the approaches across the group and describe how they were scientific, yet how they also differed in design. Results indicate this approach was effective in enhancing participants' conception of multiple methods. . The correlation of outcomes with explicit teaching emphasis is consistent with other reports (e.g. Akerson, Morrison, & McDuffie, 2006; Bianchini & Colburn, 2000; Khishfe & Abd-El-Khalick, 2002).

Despite favorable developments with the Trial B participants, their resultant level of NOS understanding was limited. The results suggest room for further advancement. Only a few held well-articulated post-internship views that were supported by appropriate examples. These results are evident in Table 4 by the frequency of single "+" designations as compared to "++" or "+++" which represent more sophisticated, deeper, NOS conceptions, as described for this study. Few reached levels beyond "+" for any aspect. A notable exception lies within the "multiple methods" category, with four participants demonstrating more advanced (++) views. Those four participants attempted to relate their research experiences to their NOS views. A few such responses were clearly related to their research, and demonstrated growth and depth in NOS conceptions. Given that participants had multiple opportunities to discuss and reflect upon variation among scientific methods, the results suggest that repetition and consistent reflection on real experiences may have aided these participants to develop more sophisticated understandings of this aspect compared to other aspects. Similar progression from "mimicry" or rote learning of a list of aspects to more meaningful conceptual understandings of NOS have been reported by others (Clough, 2006; Lederman et al., 2001; Schwartz & Lederman, 2002).

With respect to recognizing the social and cultural influences surrounding science, participants transitioned from viewing science as "culture- free" to viewing science as defined and limited by funding and political decisions. More participants voiced this latter view after their research experience than before (Table 4), suggesting an evident influence of continued funding within their settings. The influence of economics, politics, and social ethics on *what* scientists investigate does drive the scientific community and is an often-overlooked issue within the classroom. Those with this view were designated with emerging (+) views because they recognized an influence of society on what scientific knowledge is pursued. They did not, however, necessarily recognize an influence on *how* science is practiced. Again, this latter position is considered a more sophisticated level of understanding of the socio/cultural NOS.

We can speculate that advancing to this degree of sophistication may first require awareness of influences on the "what," such as what questions are asked in science. Similarly, understanding the theory-laden nature of science may entail a prerequisite of acknowledging unavoidable personal subjectivity in science. Understanding that theory directs observations and investigations, and such direction is a positive, unavoidable, aspect of science and scientific inquiry, may require a transition from viewing subjectivity in a negative light to viewing subjectivity in a positive light. Discussion about real examples may facilitate this transition. The results here suggest possible prerequisite elements needed for a sophisticated and deeper understanding of NOS that may be important areas for further research.

Conceptions of Nature of Science: Room to Grow

Comparing the learning outcomes between the program with NOS emphasis and the one without provide an encouraging insight into the potential of using explicit/reflective NOS components in association with full-immersion research internships. The gains from the program with NOS emphasis in Trial B also suggest there is potential for further advancement. The recommendations for "quality professional development" (Loucks-Horsley & Matsumoto, 1999) include providing (1) cognitive dissonance to challenge teachers' existing knowledge; (2) support for teachers to think and clarify their knowledge; and (3) challenges and support that are connected to teachers' contexts. The program with NOS emphasis in Trial B included these elements, but to varying degrees. Review of the seminar videotapes in Trial B indicated that these elements existed but did not always result in meaningful discussions. The excerpts provided in the Appendix are representative of the group discussions, and contain instances where NOS instruction could have been extended. The excerpt from "the tube" activity provided above includes suggestions for additional NOS explicit/reflective instruction. In such instances, the instructor might be able to probe further and facilitate deeper reflection. This may encourage a transition from rhetoric to elaboration with supporting examples, and from superficial affirmations to deeper understanding of the underlying philosophical features of NOS.

Also, discussion with the teachers, perhaps through a conceptual change model (Abd-El-Khalick & Akerson, 2004; Clough, 2006), may assist them in expanding their understanding of subjectivity beyond personal bias and experience. To improve NOS understanding, we suggest there be increased "challenges and support", through explicit NOS instruction and reflection opportunities by which teachers can clarify and compare their views with experiences and each other. Putnam and Borko (2000) referred to the importance of establishing a "critical, reflective discourse community" wherein teachers and university-based researchers or staff developers establish a reflective stance to enhance learning.

Conclusions and Implications

The significance of this study lies with the comparison of learning outcomes from engaging teachers in a full immersion scientific research experience with and without explicit NOS attention. Although the results are consistent with prior studies involving other types of internships, this study should help lay to rest the nagging assumption that engaging in authentic scientific inquiry is sufficient to engender desired conceptions of NOS. The results of this study are consistent with others demonstrating the importance of explicit/reflective NOS instruction toward promoting scientific literacy (Lederman, 2007). Programs with nature of science-related goals that also involve science research experiences, regardless of the nature of the experience (short term, peripheral, or full immersion), should consider group sessions wherein NOS issues are presented, discussed, and reflected upon in science contexts. Schwartz and Crawford (2004) detail three elements of effective NOS instruction within inquiry contexts. These are (1) explicit teaching, (2) reflection opportunities, and (3) a perspective that NOS is not something that one does, but something that one learns about. "We have shown that regardless of level of inquiry, one does not 'do nature of science,' and learning *about* NOS does not occur unless learners are challenged to do so" (Schwartz & Crawford, 2004, p. 350). The results of this study demonstrate the efficacy of these claims. Trial A participants were "doing science" in a full immersion research experience, but learned little about NOS. Trial B participants were "doing science" in a full immersion research experience and learning about NOS through readings, explicit activities, lectures, and discussions. Likewise, this study further emphasizes that even within a group-sharing environment that brings NOS issues to bear, one does not automatically connect ideas to experiences unless challenged to do so. In addition to explicit instruction, internship programs need to provide reflection opportunities and scaffolding wherein learners assume ownership of their views by formalizing, comparing, and challenging their views in relation to the variety of research experiences brought to the discussion.

This study raises several questions for further investigation. Are there consistent and predictable transitions in developing sophisticated NOS conceptions? Considering developments in NOS views in terms of a continuum, as opposed to a naïve/informed dichotomy, may help tease out step-wise transitions and related conceptual barriers. The analysis of NOS instruction suggested explicit teaching does not ensure reflective opportunities, even within the context of a science research internship. Investigating impacts of reflective prompts on furthering NOS conceptual development is warranted. We have a sense of the importance of the instruction and reflection opportunities in the context of science research internships. However, what is the role and impact of the research experience itself on learners' conceptual and pedagogical developments? With regard to teaching, how does the knowledge to teach NOS develop and how can such knowledge be facilitated to include explicit *and* reflective pedagogical domains? Finally, an important next step will be to examine the impact of science research internship programs that utilize explicit/reflective NOS instruction on teachers' classroom practices and student learning of NOS.

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Appendix

Instructional episode: Tricky Tracks (Lederman & Abd-El-Khalick, 1998). Explicit episodes noted in **bold.**

T: Puts overhead of first "tracks" and calls for observations.

Ss say they see tracks. A student says there is a smaller bird that gets eaten by a bigger bird.

T: Now, what do you think has happened here?

S: There appears to be a struggle.

T: Do you want to elaborate?

T: Does anyone want to give a different explanation?

S: I think the smaller animal sped up and one of the animals maybe flew off. It was a type of predator/prey interaction with the other animal.

T: You say the other animal. You mean it may not have been a bird?

S: It is possible. The tracks indicate that.

T: Let's get back to the first question I asked you. We were talking about what you observed. Some of you started talking right away about prey and animals. Do you see animals up here?

S: No.

T: What do we see up here?

S: tracks.

T: Are they tracks? Are we inferring they are tracks?

S: How deep do we need to go on this?

T: What I am saying is that science demands evidence. It is important to know the distinction between observation, what you observe – the tracks, and inferring – what would be the inference here?

S: they are birds.

T: These are birds. These are inferences. It is important to…as you go through your research…here is another example…..

T: give me an example of an observation here [OH of tracks again. Elicits observations of tracks and distances between them]

T: From those observations, what inferences can you make?

S: It picked up speed.

T: We can't see that it picked up speed, but it is an inference.

[Discussion of time tracks laid down. S says that if there was a struggle, there should be some wing scruff marks.]

T: We need to make the distinction for ourselves the importance of observations and inferences. I showed this to scientists and they immediately made inferences. I did too. Even when I said , "What do you observe" they said "there are two birds" immediately….We really need to identify……

S: As adults I think there is a strong need to get closure on things like this. When I first saw this I thought I have to draw a conclusion that summarizes. It is like kids taking a test. They have to get the right answer, make a choice for the answer.

T: This is very true. [Reinforces prior Ss comment about perspective]. The other part I want to bring forth is that we always think scientific knowledge is produced and there will be a correct answer, and absolute answer. Our students are asked to give that right answer. Yet we've heard all these possible answers. We have to recognize there may be more than one possible answer as we move to figure things out. Once a particular question has been identified and evidence supports an answer, then we move into theories or alternative knowledge, laws. But as we begin to study questions, like you will in your own research, there are many possible answers. Nothing is absolute. Yes we are driven by the need to reach a conclusion as you pointed out. Recognize when you are inferring. Science demands evidence. We bring…whenever we look at evidence, we are bringing our perspective in to make those inferences.

2. "OLD WOMAN/ YOUNG WOMAN" (Lederman & Abd-El-Khlaick, 1998)

T: What do all see here?

S: old woman

S: young woman

T: how many can see the young woman?

S: you are so fixed on one that you can't see the other one.

[Ss try to see both.]

T: Why do you think I showed this?

S: So we could see there are different ways of looking at the same problem.

T: Again so that in science we can look at the same evidence in different ways. Scientists as they view the evidence, they bring their values, their background, they look at the same evidence in different ways.

S: These are not often the values we support and encourage in our classrooms. We want students to draw the conclusions we want them to get. We want them to see it our way.

S: Some of it is necessary. We can't have an alphabet unless you see it my way.

T: In science, your training and background allows you to see evidence in different ways. You all can see that right? Do you want to add anything to that, Lisa, as a scientist?

3. NOS LECTURE/DISCUSSION OF ASPECTS

T: The distinction between observation and inference, which we began talking about…inferring what is going on, making observations…**scientific knowledge is the product of human inference and of creativity. You had to use your creativity today in making those models.**

[Referring to the overhead]

Scientific knowledge is empirically based, based on observations and experimentation.

Scientific knowledge ...both **theories and laws** …one of the biggest myths in science…that theories become laws. They are two distinct bodies of knowledge. **They are both tentative and subject to change. Michael pointed that out today when he said we don't know more until we get more technology. The knowledge we have today is subject to change.**

Scientific models such as the ones you created today are not copies of reality, rather they are inferred constructs and help explain observed phenomena.

While theories attempt to explain observable phenomena, laws are descriptions of discernable patterns.

We will be talking about this next week.

Other myths…scientific laws and other scientific concepts are absolute.

You'll see this one in many science textbooks. There is a general and universal scientific method….That is how science is conducted in all areas of science. **Is that a myth? Or are there other ways in which scientific knowledge can be gathered? For example, you are out in the field and notice a plant like this in front of you. [Ss have cactus plants]. Do you have to perform an experiment to expand scientific knowledge in this area? Would gathering information about this particular plant, whatever it is, be sufficient to expand our knowledge of this plant?**

S: Yes.

T: I want you to think about that because even in the research you are doing, some of you are doing experimental science and some of you are doing descriptive science. What would be a good example of descriptive science?

S: Dietary habits of [unclear]

T: Okay, dietary habits. Gathering information to contribute to the body of knowledge. Anybody else?

S: I am looking for species diversity and canopy height density. It would be descriptive.

T: okay.

T: Please continue reading the handout and be ready to discuss next week. [directs Ss attention to the cactus plants for beginning of inquiry activity: Ss make observations].

4. MYSTERY BONES CREATURE RECONSTRUCTION

T: How many have creatures that are four legged? How many are walking on legs? How many are swimming? (2) How many are flying? None of them are flying. Okay.

T: This is a really good exercise because it does simulate what you would do in the field. Obviously you are missing some things from the field. Jennifer was pointing out she would like to have more information. She has looked at a lot of fossils herself with her fossil leaves.

T: This exercise holds a lot of aspects of NOS. Tentativeness. What kind of things fit in with tentativeness?

S: We decided to keep changing our minds.

T: Also, with more information, with better technology or a better site or if we could see the type of environment it lived in, our knowledge of it would change. Another aspect is observation and inference. You are inferring here. In what ways?

S: I know absolutely nothing about this. I matched round ones with round ones. That is not very scientific.

T: So you are inferring the round ones go together.

S: I am inferring it is a predator from the teeth.

T: Are we bringing any prior knowledge or bias into this?

S: Yes. We are assuming the upper and lower jaws go together.

T: That is our knowledge we are bringing to this to interpret. Scientists as they interpret data have that prior knowledge and that bias. We can see that because you all have different interpretations from the same data. You are all bringing your different knowledge and biases to the table here.

T: Here is the "answer." Veronica, you are a bird person. How could you have missed this?

T: Were you all surprised?

S: Yes.

T: How come nobody figured out it was a flying creature?

S: We never thought about it.

T: Our preconceptions. Most everybody, except two of you, thought it was a land-dwelling critter. When we think about dinosaur bones we have that picture in mind that it has four legs. Scientists have these biases too. 'They are human too.

T: The other thing I want to talk about is creativity. Do you think you had to use creativity to do this activity?

S: Yes.

T: You had to use creativity and imagination to interpret this data. It's not that clear cut. That is one of the myths of science, that scientists maybe use creativity in designing an experiment but after that the numbers just fall out. But they have to use creativity and imagination all throughout the process, in their analysis and design all throughout. In your myths reading, this is a typical view of how knowledge is produced. Creativity comes to play in this whole process.

T: I want to give one last handout today. This one looks at 8 aspects of NOS (VNOS article).

Journal assignment: Read article. Than write connection between NOS aspects and research experiences.