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The Influence of an Intensive and Integrated Place-Based Professional Development Program on Teachers' Views of the Nature of Science

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Appropriate views of the nature of science are vital to scientific literacy yet rarely taught in US schools primarily due to naïve NOS views held by teachers. Thus, most school teachers need further educational NOS experiences and instruction. Science education literature suggests teachers can learn NOS through both implicit (learning through doing) and explicit (precise utilization) professional development opportunities. Through an integrated field studies teacher professional development program (*A River Runs Through It [ARRT]*) we implemented both implicit and explicit NOS instruction to see if the combination of methods would improve NOS beliefs following the program. Results obtained from pre and post *VNOS-C* (see Appendix A) surveys show a modest post-test increase in teachers' informed NOS views in all NOS aspects (except Inferential which remained the same), supporting the notion of using both implicit and explicit instruction in teaching the nature of science. In the context of a place-based, field oriented and naturally integrated watershed, our work offers insight into the value of using both implicit experiences and explicit instruction in the teaching of the nature of science for changing participant views of NOS. However, due to the large number of naïve post-test NOS views in Empirical, Theory vs. Law, Inferential, Scientific Method, and Tentative aspects we realize extended NOS experiences and instruction are necessary if science teacher educators expect to elicit dramatic and sustained change in teacher NOS beliefs. Our study demonstrates that the combination of implicit and explicit NOS instructional methods in teacher professional development programs could be a meaningful method of impacting teachers' NOS beliefs as we saw an increase in all NOS aspects from pre to post with the exception of one area which remained the same.

Keywords: nature of science, implicit instruction, explicit instruction, integrated field studies, professional development

For many decades we have heard reports that students in the United States do not know much science by the time they graduate from high school and that the science they do learn is often a surrogate form; a dull, lifeless and often useless list of facts to memorize (AAAS, 1993; NRC, 1996; NGSS, 2013a). For those who know and do science, school science that is found in most K-12 textbooks does not match up to our experiences because it is often not at all like real scientific inquiry. The science scientists know and practice, the very nature of science, is dynamic and logical, driven by curiosity and a need to find out. It is fed by inquiry and influenced by new discoveries and an active set of cultural influences (AAAS, 2008). These are not new ideas; that school science is not real science, that real science should be taught in schools, and that students should gain practical understandings of the nature of science. Educators and educational researchers have for many years endorsed efforts to nurture informed views of the nature of science (NOS) in students (i.e., Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) in an attempt to spark students' interest in the area and produce a more scientifically literate society. The national standards for scientific literacy (AAAS, 1993; NRC, 1996; NGSS, 2013a) as well as all of the state science standards consider deep understandings of NOS a vital part of scientific literacy for any student regardless of whether they wish to pursue a career in science or not. Being scientifically literate allows individuals to have a greater understanding of issues they encounter on a daily basis in the media, government, and personal life experiences (Hazen, 2002), and having accurate NOS perceptions strengthens scientific literacy. Further, in order to build a culture of more scientifically literate individuals holding well informed NOS views, there needs to be an emphasis on learning scientific principles and concepts through hands-on inquiry-based practices that are representative of real science (AAAS, 1993; Hazen, 2002; NRC, 1996; NGSS, 2013a). The National Science Teachers Association (2000) Preamble to their Nature of Science position statement reads, in part, "All those involved with science teaching and learning should have a common, accurate view of the nature of science."

Our Study and Research Question

One common explanation for the absence of real science in classrooms is that teachers have very limited and naïve views of the nature of science themselves. Teachers teach the science they know and if this does not represent the best conceptions of the nature of science, their students will not be exposed to it. It follows that in order to improve scientific literacy in schools, teachers need further educational experiences in NOS. We believe that even practicing teachers with little background or experience in science can learn the nature of science through participation in well-crafted professional development opportunities that include implicit and explicit instruction in NOS. We support the notion that if teachers own a more informed view of NOS, their science teaching will gain vitality and scientific literacy will begin to thrive and grow in their classrooms. Appropriate experiences may help facilitate the portrayal of science from a "rhetoric of conclusions" (Clough & Olson, 2012) to teachers representing the best conceptions of NOS. Without appropriate experiences, teachers may ask themselves, "How do I or can I help students understand the nature of science if I do not understand NOS myself?" (NGSS 2013b). Our research explores the influence of a professional development program entitled *A River Runs Through It* (*ARRT*) (grant-funded by the Ohio Board of Regents*) on ARRT* teacher's NOS beliefs prior to and after the program to assess the impact of the implicit experiential NOS experiences combined with the explicit NOS instruction that teachers received. Specifically, the research question guiding this study was: *Does A River Runs Through It (ARRT), an intensive and integrated place-based professional development program designed to provide NOS implicit experiences and explicit instruction, influence teachers' views of the nature of science?*

What would a more informed view of NOS look like in practice in school classrooms? Abd-El-Khalick and Lederman (2000a) state: "no consensus presently exists among philosophers of science, historians of science, scientists and science educators on a specific definition for NOS" (p. 666). Neither is it free of structure, of historical and logical order. As mentioned above, science is a dynamic process and not one scientific method or formulaic, universal checklist to follow (Tsai, 2006). Scientists tend to be lifelong learners because science demands it. Sadly, many teachers still hold empiricist perspectives of science and assume that scientific knowledge is the discovery through a universal scientific method (Tsai, 2006). Instead, teachers should come to know science as a continual construction of meaning that emphasizes the tentative nature of science knowledge, the theory-laden quality of scientific exploration. Like scientists, teachers should come to understand the role of conceptual change in the progressive development of their own scientific understanding as well as their students' (Tsai, 2006).

Research Concerning Teachers' Views of the Nature of Science

Although there are variations in the descriptions of the nature of science, we refer to NOS as defined by Abd-El-Khalick, Bell, Lederman & Schwartz (2002). The NOS aspects addressed in this study (Empirical, Tentative, Influential, Creative, Theory-Laden, Social and Cultural, Scientific Method, Theories and Laws) are defined in Table 1. We feel that these various aspects combined provide a complete and practical working definition of NOS. The literature suggests that NOS instruction can be implicit or explicit. Implicit attempts utilize science process-skills instruction or engagement in science-based inquiry activities to improve science teachers' conceptions of NOS (Abd-El-Khalick & Lederman, 2000, p. 665). Although at first glance, this method would seem to be effective, there is some controversy about its long-range effectiveness. A limited number of studies exploring the implicit NOS instruction of pre-service teachers show slight improvement in pre-service teachers' NOS views (e.g., Palmquist & Finley, 1997). Others examined NOS changes in practicing teachers' views and found mixed results due to implicit NOS instruction. For example, although Scharmann and Harris (1992) found that some in-service teacher attitudes changed with implicit instruction, other researchers indicate insignificant changes (e.g., Haukoos & Penick, 1985). Consequently, the research results are not conclusive regarding the influence and appropriateness of implicit instruction of NOS (Abd-El-Khalick & Lederman, 2000a).

In contrast, explicit instruction has been shown to be useful in eliciting positive NOS attitudinal changes in practicing and pre-service teachers. According to Tsai (2006), science teacher education courses that integrate ideas about the philosophy of science, contemporary learning theories, and activities led to changes in teachers' views of the nature of science. Tsai suggests that practicing teachers showed more agreement with constructivist views about science at the conclusion of the course, but their position toward the empiricist views about science remained statistically unchanged. Due to their prior academic experiences in science and rich practice in teaching science, the in-service teachers might have strongly developed (possibly empiricist-oriented) views about science that were resistant to change (Tsai, 2006). Furthermore, approaches that utilize elements from history, philosophy of science, and/or direct instruction of NOS are more effective in achieving adequate conceptions of NOS than approaches that utilize scientific process-skills, instruction, or non-reflective inquiry-based activities (Abd-El-Khalick & Lederman, 2000a).

Context of Our Study

As the historic rivers run through the Midwest, they bring outstanding opportunities for invigorating science and mathematics education. This teacher professional development program, entitled *A River Runs Through It* (*ARRT*) (grant-funded by the Ohio Board of Regents), is based on the assumption that powerful science teaching is situated in local contexts making the study of these two historic rivers valuable for teachers. The program was designed as an integrated watershed program to offer practicing teachers with professional development focusing on hands-on implicit NOS experiences in the field as well as explicit NOS classroom discussion. Field work in the watershed area, classroom work on pedagogical applications, and technology integrated throughout were set up to enable participating teachers of science and mathematics to develop knowledge, skills and understandings as represented in the Ohio Academic Content Standards as well as new facility with field-based and inquiry methods of teaching. Extensive field work as, well as intensive collaboration with working scientists, naturalists, mathematicians, and other local experts in related fields were a large component of this professional development program.

The program consisted of two phases: 1) an intensive and integrated summer institute that ran Monday through Thursday from 8:30am until 5:00pm for two weeks; and 2) an academic fall session application phase (three 3-hour long face-to-face class sessions). Phase 1, the summer institute, mainly focused on *NOS implicit experiences* and had three components: a) field-based inquiry which included collecting data in the local river watersheds, including technology-enhanced water studies, soil sampling, light intensity testing, comparison of flora and fauna in different areas; b) classroom-based study in which participants engaged in data analysis, interpretation and integrated study; and c) an instructional design component in which participants used their new understanding to design curriculum materials for their own classrooms. Phase 2, the academic fall sessions, mainly focused on *NOS explicit instruction* had three components: a) lesson planning; b) lesson plan slide show presentations and presentations of draft action plans; and c) culminating activity and action plans. Both phases however, because of the inherent nature of our program, at certain points in time, focused on both *NOS implicit experiences and explicit instruction.*

In *ARRT*, teachers were exposed to NOS through integrated place-based field study that utilized science process-skills instruction and engagement in science-based inquiry activities (i.e., Abd- El-Khalick & Lederman, 2000a). Participants, in field study groups, sampled water, surveyed geological formations, made observations and collected data using technology during field trips and interpretive walks. Our specific content focus was watershed ecology in a rather broad sense. We incorporated river ecology, wetlands, natural history as well as human ecology; farming, human settlement, architecture, history, folklore, art and music. Participants also regularly discussed specific issues pertaining to the nature of science to collaboratively construct meaningful understanding in situ, while participating in the field study. We also more explicitly approached NOS through discussion, guided reflection, specific questioning in the context of classroom science activities (including inquiry-oriented activities, examples from history of science, and traditional classroom-based science activities) (i.e., Schwartz et al., 2002).

During the *ARRT* Summer Institute, participating teachers acted as environmental field scientists studying, exploring, and experimenting with their natural surroundings implicitly experiencing the nature of science. Explicit, direct instruction of NOS was later integrated in a rather Socratic way into the fall discussion sessions. We consider this explicit instruction because the instructors actively looked for opportunities to directly teach the basic NOS aspects through questions and comments. Curricular details regarding the content of

NOS instruction during the Socratic discussion sessions focused on all aspects of NOS. These Socratic discussion sessions, in part, included collaborative groups meeting in "Implementation Sessions" to support each other in putting their new learning of NOS aspects into practice with their own students. We hypothesized that the combination of lived experiences *in practicing guided scientific inquiry* with explicit direct instruction of NOS issues would influence teachers' perceptions of the NOS and possibly transfer into their daily teaching. Although constructive NOS views alone are insufficient to drive teacher practice, they are still a necessary condition (Abd-El-Khalick & Lederman, 2000a). Additionally, professional development contexts that treat inservice teachers as professionals are more likely to promote change in certain aspects of teachers' views about the nature of science (Schuster & Carlsen, 2006). Examples of summer institute activities that treated practicing teachers as field scientist professionals include but were not limited to:

Experiential fieldwork example: Water sampling. One example of *ARRT's* attempt to provide teachers with experiential learning where they explored NOS implicitly and were treated as field scientists is described here. Teacher participants began the day in the classroom at the local Botanical Gardens learning about Explorer® technology and probes for collecting water sampling data. The instructors for this component of *ARRT* were a high school ecology teacher and a technology expert. Curricular details regarding the content of NOS instruction during this experiential fieldwork on water sampling focused much on the empirical (observation of the natural world) and inferential (distinction between scientific claims and evidence on which such claims are based) aspects of NOS. This included the instructors leading the participants in discussion and demonstration of the probes and their function: temperature, conductivity, pH, and dissolved oxygen levels. In addition, participants took notes and were given ample opportunity to ask any questions they had that were answered by the instructors.

Class moved to the nearby pond at the local Botanical Gardens where participants applied the formal instruction in a hands-on application by collecting water data from different locations around the pond. Working in groups of three or four, all participants recorded data in their field journals and took turns handling the Explorer® probes. Through a working lunch, the group gathered outside to discuss their results and the practical implications of different water sample data collected from various locations around the pond. Participants were enthusiastic about their discoveries and sharing of their results.

Following lunch, in small groups participants connected their Explorer equipment to laptop computers in the classroom to work with the data charts and tables. Each group created a power point presentation using the Explorer® software and their water sample data. According to the participants, the activity could easily be reproduced in a real classroom setting. In fact, some of the teachers that already teach water quality were looking forward to using the Explorer® equipment with their students rather than traditional "snap kits."

Method

Participants

Twenty practicing teachers and 4 graduate students (*N*=24) participated in all phases of the *A River Runs through It* (*ARRT*) program. This article reports the findings of only one of the research foci employed in relationship to the larger project. For this report, we focus on ten of the twenty practicing teacher participants who completed both phases of NOS data collection. Although all twenty completed the pre-test, ten chose to not participate in the post-test. We are uncertain as to why these ten participants self-selected out of the study, but believe it may have something to do with the nature of the post-survey being conducted after the *ARRT* program was finished. Additionally, the post-test was mailed to teachers with a follow-up email rather than having participants complete the survey in a controlled environment (classroom) as done with the pre-test. Gender composition of the ten participants who did complete both pre- and post-tests was made up of mostly female (*n*=8), all self-identified as White, non-Hispanic teachers of public (*n*=6), urban (*n*=4), suburban (*n*=5), and/or rural (*n*=1) schools in Northwestern Ohio and Southeastern Michigan. Participants' current grade level teaching was distributed between Elementary (K-3) (*n*=1), Intermediate (4-6) (*n*=3), Middle of Junior High (6-8) (*n*=4), and High School (9-12) (*n*=2). Great variance existed in our participants' current subject area teaching: math only (*n*=1), science only (*n*=5), social studies and language arts (*n*=1), art (*n*=1), gifted and talented (*n*=1), special education (*n*=1).

Instructors

Three professors and four instructors were responsible for *ARRT* program instruction and field study inquiry. Instructors held diverse backgrounds and fields of specification to meet the program objective of integrating field study, environmental education, and multiple content areas. The professors included: 1) an environmental scientist/education professor, 2) a geologist/environmental science professor, and 3) and an education professor with a literacy and math content focus. The other instructors consisted of high school biology and environmental education teacher, a technology expert from the University, and two doctoral candidates from the college of education, each with a focus in science education.

In addition to the seven key instructors, numerous guest instructors and content specialists assisted in the program's field trip experiences. For example, when touring local historical sites of Indian battle fields, a local Archeologist and Historian led the discussion and visit. When exploring an excavation site of a local Island Civil War prison for southern officers, the head archeologist and an archeological "rubber specialist" discussed their work and findings. Metropark naturalists and Botanical Garden staff also participated in other field excursions. These field specialists and local experts contributed great depth to the teachers' study and understanding of the specific disciplines being explored. They also implicitly portrayed science as a dynamic field of study where inquiry of the natural environment is essential in building upon current scientific knowledge.

Instrumentation and Procedures

Instrument

VNOS-C. During *ARRT*, we conducted three applications of the "Views of Nature of Science Questionnaire form C" (*VNOS-C)* (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). The *VNOS-C* is a ten item open-ended questionnaire focusing on NOS principles such as: empirical, tentative, inferential, creative, theory-laden, social and cultural, myth of the "Scientific Method," and nature of and distinction between scientific theories and laws and is used to assess participants' base level understanding of the NOS principles. As a result of previous studies and follow-up interviews, there is support for a high confidence level in the validity of the *VNOS-C* for assessing the NOS understandings of a wide variety of respondents (Lederman et al., 2002).

Longitudinal surveys collect information at different points in time in order to study changes over time (Fraenkel, Wallen, & Hyun, 2012). As a panel study, the researchers survey that same sample of individuals at different times during the course of the longitudinal survey (Fraenkel, Wallen, & Hyun, 2012). This survey was administered to the same group of teachers at three different points in time. First, the *VNOS-C* survey was given to all participants during the first day of the Summer Institute. The second application of the *VNOS-C* occurred during the second (of 3) fall discussion meeting approximately three months after the summer institute concluded. This was a clear diversion from the *VNOS-C* protocol with Vygotsky's belief in mind "that much of what we learn we learn from others" (Phillips & Soltis, 1998, p. 59). Vygotsky argued that learning and development is a social, collaborative activity and that the Zone of Proximal Development can serve as a guide for curricular and lesson planning. Vygotsky used the term zone of proximal development to describe the region between the learner's spontaneous level of knowing and thinking, and the level the learner can reach in problem solving with assistance (Carin, Bass, & Contant, 2005, p. 89). Vygotsky believed that school learning should occur in a meaningful context and not be separated from learning and knowledge students develop in the "real world". Therefore, out-of-school experiences should be related to the student's school experience. For the third application, we mailed surveys to all of the participating teachers at the beginning of January; approximately six months after the summer institute and about three months after the VNOS-C discussion meeting.

VNOS-C application #1: Survey on first day of the Summer Institute. We modeled our program after the instructional strategies for conceptual change proposed by Nussbaum and Novick (1982) where we first revealed the practicing teachers naïve views of NOS during the VNOS-C application #1 on the first day of the summer institute. Teachers in the *ARRT* Summer Institute completed the *VNOS-C* independently on the first day of the program. Rather than having participants in the controlled environment of the classroom, as suggested by Lederman (2002), teachers were asked to take a clip board, the survey and find a comfortable place out of doors in the local Botanical Garden, our daily meeting place for the summer institute. This departure from the protocol suggested by the authors is more consistent with our philosophy of informal learning through inquiry and the use of field study in the environmental education program (see *ARRT* philosophy above). As in Lederman (2002) teachers were allotted one hour to answer the questionnaire. See Appendix A for items on the *VNOS-C*.

VNOS-C application #2: Fall discussion meeting. As described earlier, the *ARRT* program included three fall evening follow-up classroom work sessions designed to continue working on the implementation of what they had learned from the Summer Field Institute into their current teaching. The summer institute provided opportunities for the teachers to evaluate their preconceptions through field work (Nussbaum & Novick, 1982). The second of our fall meetings was dedicated to a discussion of the NOS. Small group and whole-group discussion provided opportunity to create cognitive dissonance with their preconceptions based on their summer field work (Nussbaum & Novick, 1982). Teachers worked in their summer institute field study groups of four to five participants to collaboratively construct group responses to *VNOS-C* questions. Each of the five groups was assigned two of the 10 *VNOS-C* items. They discussed the meanings of the questions, possible answers and used markers to write group responses on poster board paper. When the group was done, they hung their group responses on the wall of the classroom. In addition to giving the specific answers to the assigned questions, they were asked to describe what implications their answers have for their teaching of science and other subjects.

When each field study group stood up to present their responses to their assigned *VNOS-C* items, invigorating whole group discussion occurred where instructors were able to facilitate conceptual restructuring in regard to informed NOS views (Nussbaum & Novick,

1982) through explicit NOS dialogue. Participants were required to use examples from the Summer Institute as evidence for their claims in order to illustrate the impact of the field work in regard to their NOS views demonstrating how implicit instruction had impacted their NOS beliefs. Instructor led explicit NOS dialogue with participant shared implicit NOS experiences were intentionally combined to facilitate deeper NOS understanding through the deliberate meshing of explicit and implicit NOS instruction.

Formal NOS assessment of individuals *was not* a goal of this meeting. Rather, the appropriate understanding of NOS principles where the knowledge was collectively constructed by the teachers "whose purpose [was] to share their expertise in order to construct and negotiate meaning" (Wink & Putney, 2002, p. 13). Socially constructing meaning and beliefs about NOS to elicit greater ownership over these beliefs was the primary desired outcome at this session.

As Abd-El-Khalick and Lederman (2000b, p. 1059) state:

> To be able to effectively teach NOS to k-12 students, science teachers need to have more than a rudimentary or superficial knowledge and understanding of various NOS aspects. Teachers need to know a wide range of related examples, explanations, demonstrations, and historical episodes. They should be able to comfortably discourse about various NOS aspects, contextualize their NOS teaching with some examples or stories from HOS, and design science-based activities to render the target NOS aspects accessible and understandable to k-12 students.

VNOS-C application #3: Post survey mailed to teachers only. Individual teachers' NOS views were again formally assessed sixteen weeks into the regular school year, six months after the Summer Inquiry Institute and three months after the fall NOS discussion session. This time lapse allowed teachers to get back into their regular routines and to field test the lesson plans they produced as an outcome of the *ARRT* Summer Institute. Because busy schedules did not allow another evening session, it was impossible to gather teachers together in a controlled environment for this round of data collection. Teachers were mailed the *VNOS-C* and asked to complete it without the use of outside materials and return it to the researchers. An email reminder was sent out to all who did not return their post-survey within two weeks of the initial mailing. Data from this phase was used for comparison to teachers' baseline NOS understanding and in comparison to the Fall Discussion Session to see if *ARRT* experiences may have contributed to a lasting change in NOS beliefs. Our return rate for the mailed surveys was 50%.

Data Analysis

Data collected for the *VNOS-C* individual teacher responses at time 1 and 3 were coded according to aspects of NOS as defined by Lederman, Abd-El-Khalick, Bell, and Schwartz (2002). Their definitions for the categories described in Table 1 were used as the basis for determining if responses provided in this study were more informed or more naïve views of the nature of science. Interrater reliability is crucial when multiple researchers are analyzing data. The researchers independently analyzed this data, compared their analyses, and resolved any discrepancies with further consultation of the data arriving at a consensus (Lederman, Abd-Ed-Khalick, Bell, & Schwartz, 2002). First, the responses were evaluated for accuracy where researcher's rated NOS response as representing either more informed views or more naive views for each NOS aspect. For example, one respondent wrote that: "Imagination and creativity are used in presenting 'hard science' to the public, but is not tolerated among those following strict scientific methods." This response was considered a more naïve view for the Creative aspect of NOS. Another respondent stated that: "Scientists absolutely must use imagination and creativity…in coming up with new ideas, being able to look at something and see things that no one else has. Looking at things in new ways, using tools/technology for other purposes." In contrast to the first example, this response was rated an informed view for the same NOS aspect. Following this preliminary round of data analysis, researchers looked for common themes, patterns, and naïve conceptions in the responses (i i.e., Akerson, V. L., Morrison, J. A., & McDuffie, A. R., 2006).

Table 1
Nature of Science Aspects Defined

NOS Aspect	**Definition**
Empirical	Science is based, at least partially, on observations of the natural world.
Tentative	Scientific knowledge is subject to change and is never absolute or certain.

Inferential	The crucial distinction between scientific claims and evidence on which such claims are based.
Creative	The generation of scientific knowledge involves human imagination and creativity.
Theory-Laden	Scientific knowledge and investigation are influenced by scientists' theoretical and disciplinary commitments, beliefs, prior knowledge, training, experience, and expectations.
Social and Cultural	Science as a human enterprise is practiced within, affects, and is affected by a larger social and cultural milieu.
Scientific Method	The lack of a universal step-wise method that guarantees the generation of valid knowledge.
Theories and Laws	Lack of a hierarchical relationship between theories and laws.

Results

A greater number of informed views were found at the end of *ARRT* program than at the beginning, for seven of the eight *VNOS-C* categories: Empirical, Tentative, Creative, Theory-Laden, Social & Cultural, Scientific Method, and Theories vs. Laws NOS aspects. However, more Informed Views for the Inferential NOS remained about the same as it was in the pre-test. None of the NOS aspects regressed to having a greater number of more naïve views at the end of the program than in the beginning. See Table 2 for *VNOS-C* application results and Table 3 for examples of more informed and more naïve view examples from our participants for each NOS category.

Persistent Naïve Conceptions

Common themes in misconceptions among participants with more naïve views at the post-test phase were examined to see where participants continued to struggle with appropriate NOS beliefs. Frequent misconceptions were found in Empirical, Tentative, Inferential, Scientific Method, and Theory vs. Law NOS aspects. Creative, Theory Laden, and Social Cultural NOS aspects did not possess common misconceptions in the post-test phase as there were so few participants (zero or one) with more naïve views of these domains.

Empirical NOS misconception themes. A common misconception found in the post-test Empirical NOS was the belief that science relies on "testing" and is "provable" or "supplies provable evidence." This misconception was described by five of the six participants with more naïve Empirical NOS views in their post-test responses.

Tentative NOS misconception themes. Science as "fact" was found as a common misconception among those with more naïve Tentative NOS views in the post-test. All six of these participants responded that science is used to "prove something true" or that scientific "laws are fact."

Inferential NOS misconception themes. Common misconceptions were revealed among those with more naïve Inferential NOS views in the post-test. With respect to the structure of an atom, five of the seven participants with misconceptions referred to technology as the leading reason for scientists' certainty of atomic structure. And four of the seven participants felt that experimentation played a role. Regarding species, six of the seven participants with misconceptions believed similar characteristics such as DNA and breeding were responsible for specific categorization of species.

Scientific Method NOS misconception themes. Of the seven participants with more naïve views about the scientific method dimension of NOS in the post-test, four referred to the scientific method as a specific step-wise "procedure" that scientists use in experimentation. While all seven suggested that the experiments elicit scientifically valid or "true" results.

Theory vs. Law NOS misconception themes. The common theme of hierarchical structure between theories and laws was evident in post-test responses from those with more naïve views toward Theory vs. Law NOS. All eight of these participants viewed theories as "unproven" and "laws (as) fact" or "proven." And three participants suggested that "theories become laws once proven."

Table 2
Pre and Post Individual Response VNOS-C Results (N=10)

NOS Aspect	**More Naïve View**	**More Informed View**
Test Time		
Empirical		
Pre-Test	7	3
Post-Test	*6*	*4*
Tentative		
Pre-Test	7	3
Post-Test	*6*	*4*
Inferential		
Pre-Test	7	3
Post-Test	*7*	*3*
Creative		
Pre-Test	1	9
Post-Test	*0*	*10*
Theory-Laden		
Pre-Test	3	7
Post-Test	*1*	*9*
Social & Cultural		
Pre-Test	4	6
Post-Test	*1*	*9*
Scientific Method		
Pre-Test	9	1
Post-Test	*7*	*3*
Theories vs. Laws		
Pre-Test	9	1
Post-Test	*8*	*2*

Table 3
Participant More Naïve and More Informed Response Examples for Each NOS Aspect Assessed

NOS Aspect	More Naïve View	More Informed View
Empirical	People who study scientific methods have the means to actually prove the relativity and validity of a situation… without proof or evidence people of science will not believe. (Item 1)	Science is done in a process that seeks clarification of ideas, while posing more questions for investigation…it tests ideas and retests ideas and relies on peer review to validate findings. (Item 1)
Tentative	A theory is a theory until an experiment comes along and makes it a fact. (Item 4)	Theories are only as good as the knowledge we posses at the time. New technology, new experiments constantly alter our scientific theories. The value of learning theories is to discover more. By knowing what is, you can question it or expand it, therefore changing the original theory. (Item 4)
Inferential	The looks of atoms are determined through experimentation and observations by the scientists! (Item 6) I think that scientists are certain about their characterization of what a species is. I think scientists used similar characteristics to put species into various categories. (Item 7)	I think scientist's first use as obvious as possible evidence that they can agree on, maybe such as gills vs. lungs vs., photosynthesis. Then they just start narrowing down the characteristics. But there is not total agreement…things change and new species are found. (Item 7)
Creative	Imagination and creativity are used in presenting "hard science" to the public, but is not tolerated among those following strict scientific methods. (Item 10)	Scientists absolutely must use imagination and creativity…in coming up with new ideas, being able to look at something and see things that no one else has. Looking at things in a new way, using

		tools/technology for other purposes…if they were not creative, how would they get the idea to experiment in the first place?
Theory-Laden	Because no one was there with their yellow notebooks to take observations so no one knows for sure (why dinosaurs were extinct)! (Item 8)	Different biases play a role. Theories rely on how experiments are set up and how data is analyzed. Since each researcher has their bias it is easy to see how they (views of dinosaur extinction) can vary. (Item8)
Social & Cultural	Science is universal because with the vast array of groups testing for results on a given topic, they should eventually result in the same/similar results. Thus the scientific results would not change the social and/or cultural values at the end but enhance the entire population as a whole. (Item 9)	I think that science is affected by the social and cultural values imbedded in individuals and groups…science is approached by people with their own religious values and beliefs. (Item 9)
Scientific Method	The scientific method involves posing a question, then postulating a series of answers, then conducting a series of controlled experiments to test the proposed hypothesis, and then seeing which of the hypotheses holds true after many trials. (Item 1)	A way to find out about something. An exercise to satisfy curiosity…derived from a natural sense of curiosity about our world and how it works. It can revolve around the simplest of questions and observations, and so can be explored at the earliest age and by all, no matter what their intellect or level of knowledge. (Items 1 & 2)
Theories vs. Laws	I believe a theory becomes a law once scientists are able to prove their theory with certainty. Laws don't change. (Item 5)	Theories attempt to explain "why" something occurs or "how" something occurs. Laws predict and don't explain. (Item 5)

Discussion

Does A River Runs Through It (ARRT), an intensive and integrated place-based professional development program designed to provide NOS implicit experiences and explicit instruction, influence teachers' views of the nature of science? Our study demonstrates that the combination of implicit and explicit NOS instructional methods in teacher professional development programs could be a meaningful method of impacting teachers' NOS beliefs as we saw an increase in all NOS aspects from pre to post with the exception of one area which remained the same. Overall, perceptions of the nature of science held by teachers in this research were more informed after completing the *ARRT* program and having returned to teach for twelve weeks. Prior research has shown mixed results for improving teachers' NOS beliefs when using implicit NOS experiential learning alone (Haukoos & Penick, 1985; Palmquist & Finley, 1997; Sharmann & Harris, 1992), or solely explicit NOS instruction (Tsai, 2006) although explicit NOS instruction has appeared to worked better (Abd-El-Khalick & Lederman, 2000a).

Teachers in this study came into the program with higher informed views in certain NOS aspects over others. For the Creative, Theory-Laden, and Social & Cultural domains of NOS, over half of the teachers in our sample entered the program with informed views. For these NOS aspects all, or all but one, of the teachers held more informed views in the post-test stage. We cannot explain the reason for this. However, we do speculate that it may have something to do with self-selection into the *ARRT* program. By this we mean it is possible that the teachers who chose to participate in our environmental education professional development program may have participated because *ARRT* goals and philosophy matched closely with their personal science education beliefs. Supporting this possibility, Creative, Theory-Laden, and Social/Cultural aspects were all specific goals of *ARRT*. It was a goal for teacher participants to learn to be creative in their exploration of the natural world around them (Creative NOS). At times they hypothesized about the nature of a river or the condition of a historical battle field based on the remains, where different conjectures were made and all could have been "right" (Theory-Laden NOS). The integrated nature of the program, combining science with local history and other content areas, promoted the Social & Cultural NOS aspect. Therefore, teachers who did not at least in part share these philosophical beliefs about science would likely have avoided applying for this intense professional development learning opportunity.

On the other hand, teachers in this study held quite naïve views prior to and after the *ARRT* program for particular NOS aspects. Over half of the teachers' views were still naïve in the post-test phase for Empirical, Tentative, Inferential, Scientific Method, and Theories vs. Laws domains of NOS. Although all of these NOS aspects increased in more informed views in the post-test, except for Inferential which remained the same, a large portion of our sample still held more naïve perceptions in the end. Most problematic were Theories vs. Laws, Scientific Method, and Inferential NOS aspects. A theme of "science is proven" or "absolute truth" found from doing science was revealed in the teachers' responses for items addressing these categories. While these results are somewhat similar to prior research (Tsai, 2006), it is nevertheless quite troubling in that teachers without appropriate NOS views are highly likely to pass these misconceptions along to their students. At the same time, this is not surprising as these naïve views may be long standing beliefs requiring more than one course to change regardless of the NOS instructional method.

Implications

In the context of a place-based, field oriented and naturally integrated watershed, our work offers insight into the value of using both implicit experiences and explicit instruction in the teaching of the nature of science for changing participant views of NOS. However, based on the naïve views still present in the post-test, specific attention should be given to NOS aspects that revolve around science as a dynamic body of knowledge that is never proven "truth" but supporting or refuting evidence. Additionally, we realize that one teacher education program is most likely not enough to elicit dramatic change in teacher NOS beliefs. Especially for those that hold very strong naïve views, as well-established beliefs are very difficult to move and much time is required to facilitate long held attitudinal changes. Time and constant support are necessary for helping in-service teachers learn to transfer appropriate NOS beliefs through their teaching of NOS in their own classrooms (Tuan & Chin, 1999). And, this is the ultimate goal since we strongly believe that engaging field-based NOS learning promotes student excitement toward and learning of science.

Questions about the value and application of implicit instruction in NOS as a specific strategy or in combination with explicit methods as delivered in *ARRT* are raised from this study. Undergraduate teacher education programs need to focus on teaching strong NOS understanding so these pre-service teachers have exposure to these views and a chance to adopt them. Teacher professional development programs addressing the nature of science need to extend longer than a summer session in order to have a competitive chance against strong naïve NOS perceptions. Providing teacher support in lesson planning throughout a school year or longer may also be a beneficial tactic in enhancing and sustaining NOS instruction in the classroom.

"The integration of scientific and engineering practices, disciplinary core ideas, and crosscutting concepts set the stage for teaching and learning about the nature of science. This said, learning about the nature of science requires more than engaging in activities and conducting investigations." (Next Generation of Science Standards [2013] p. 2). The conclusions of this research support this notion and can help inform policy development, curriculum, as well as assessment advancements. The NGSS (2013a) states:

> Quality science education is based on standards that are rich in content and practice, with aligned curricula, pedagogy, assessment, and teacher preparation and development. It has been nearly 15 years since the National Research Council and the American Association for Advancement in Science produced the seminal documents on which most state standards are based. Since that time, major advance in science and our understanding of how students learn science have taken place and need to be reflected in state standards. The time is right to forge *Next Generation Science Standards*.

Limitations

The major limitations in this study are sample size and post-test procedure. We were unable to obtain post-test *VNOS-C* responses from all participants in the *ARRT* program (a 50% return rate). The only responses we received were from those that voluntarily completed and returned the questionnaire. Therefore, we are unable to determine if this group of respondents is similar to or different from the participants who chose not to respond. As previously mentioned, we believe the reason for the lower return rate on the post-survey was because participants were asked to complete the survey on their own time and return it after the program was complete, as opposed to having teachers complete the survey when they were in class as a captive audience.

Procedurally, the post-test was not completed in a "controlled" environment. Teachers completing the post-test at their home or school without researcher observation allowed them the opportunity to use outside information in responding even though they were specifically instructed not to do this. Interviews of participants would have added to the validity of the results as they would have provided greater depth in understanding more about participants thinking. Therefore the generalizability of these results is limited based on the added instability of testing environment, small sample size, and lack of interviews.

Future Research

The teachers in this study self-selected to participate in this program. Future research should focus on a much larger sample size that includes teachers who are randomly selected to explore whether self-selection is a variable that influences the development of NOS views. A longitudinal research study is needed to establish whether an intensive and integrated place-based professional development program designed to provide NOS implicit experiences and explicit instruction will influence teachers' views of the nature of science *over time*. Researchers might consider administering the post survey in a controlled environment in order to increase the post-survey return rate as well as validity of responses. Future research should also include interviews which may provide further insight relevant to professional development programs. Also, an exploration of the effect this professional development may have on student attitudes and academic achievement is critical.

References

American Association for the Advancement of Science (AAAS) (1993). *Benchmarks for science literacy.* Washington, DC: American Association for the Advancement of Science. Retrieved from: http://www.project2061.org/tools/benchol/bolframe.html

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

Abd-El-Khalick, F., & Lederman, N. G., (2000b). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching*, *37,* 1057-1095.

Akerson, V. L., Morrison, J. A., & McDuffie, A. R. (2006). One course is not enough: Preservice elementary teachers retention of improved views of nature of science. *Journal of Research in Science Teaching*, *43*, 194-213.

Carin, A., Bass, J., & Contant, T. (2005). *Methods for teaching science as inquiry*. Upper Saddle River, NJ: Pearson.

Clough, M., & Olson, J. (2012). Impact of a nature of science and science education course on teachers' nature of science classroom practices. In Advances in nature of science research: Concepts and methodologies (2012). Khine (editor). Dordrecht: Springer.

Fraenkel, J., Wallen, N., & Hyun, H. (2012). *How to design and evaluate research in education* (8th Ed.). New York: McGraw Hill.

Haukoos, G.D., & Penick, J.E. (1985). The effects of classroom climate on college students: A replication study. *Journal of Research in Science Teaching*, 22(2), 163-168.

Hazen, R. M. (2002). Why should you be scientifically literate? *American Institute of Biological Sciences*. Retrieved from http://www.actionbioscience.org/newfrontiers/hazen.html#primer

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., &

Schwarz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39*, 497-521.

National Research Council (NRC) (1996). *National science education standards.* Washington, DC: National Academy Press.

National Science Teachers Association (NSTA). (2000). Nature of Science Position Statement. http://www.nsta.org/about/positions/natureofscience.aspx

Next Generation of Science Standards (NGSS). (2013a). http://www.nextgenscience.org/next-generation-science-standards.

Next Generation of Science Standards (NGSS). (2013b). APPENDIX H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards.

Nussbaum, J., & Novick, N. (1982). Alternative frameworks, conceptual conflict, and accommodation: Toward a principled teaching strategy. Instructional Science, 11, 183-200.

Palmquist, Bruce and Finley, Fred (1997). "Preservice teachers' views of the nature of science during a postbaccalaureate science teaching program." *Journal of Research in Science Teaching*, 34(6), 595-615.

Phillips, D. C., & Soltis, J. F. (1998). *Perspectives on learning* (3rd Ed.). New York: Teachers College Press.

Scharmann, L., & Harris, W. (1992). Teaching evaluation: Understanding and applying the nature of science. *Journal of Research in Science Teaching, 29*, 375-388.

Schuster, D., & Carlsen, W. (2006). *Science teaching as a learning profession.* Paper presented at the Annual Meeting of the National Association of Research in Science Teaching: San Francisco, CA.

Schwartz, R. S., Lederman, N. G., Khishfe, R., Lederman, J. S., Matthew, L., Liu, S. (2002). *Explicit/reflective instructional attention to nature of science and scientific inquiry: Impact on student learning*. Proceeding of the International Conference of the Association for the Education of Teachers in Science: Charlotte, NC.

Tsai, C. (2006). Reinterpreting and reconstructing science: Teachers' view changes toward the nature of science by courses of science education. *Teaching and Teacher Education*, *22*, 363-375.

Tuan, H., & Chin, C. (1999). *What can in-service Taiwanese science teachers learn and teach about the nature of science?* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching: Boston, MA.

Wink, J., & Putney, L. (2002). *A vision of Vygotsky*. Boston: Allyn and Bacon.

APPENDIX

VNOS-C Items

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?
2. What is an experiment?
3. Does the development of scientific knowledge require experiments?

   If yes, explain why. Give an example to defend your position.

   If no, explain why. Give an example to defend your position.
4. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?

   If you believe that scientific theories do not change, explain why. Defend your answer with examples.

   If you believe that scientific theories do change: (a) Explain why theories change; (b) Explain why we bother to learn scientific theories. Defend your answer with examples.
5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.
6. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting the nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?
7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence do you think scientists used to determine what a species is?
8. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypothesis formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

9. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

   If you believe that science reflects social and cultural values, explain why. Defend your answer with examples.

   If you believe that science is universal, explain why. Defend your answer with examples.

10. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?

    If yes, then at which stages of the investigations do you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.

    If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

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