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Impact of a Flashback Non-Implicit Attempt-Oriented Theory on East Azerbaijan 5th Area on High Schools Teachers' Concepts of Nature of Science in Iran

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Abstract
This study assessed the impact of a flashback, non-implicit, attempt-oriented approach to nature of science (NOS) instruction undertaken in the context of a secondary science methods course on pre-service teachers' views of some aspects of NOS. These aspects included the empirical, tentative, subjective (theory-laden), imaginative and creative, and social and cultural NOS. Two additional aspects were the distinction between observation and inference, and the functions of and relationship between scientific theories and laws. Participants were 25 undergraduate and 25 graduate pre-service high school teachers enrolled in two sections of the investigated course. An open-ended NOS questionnaire coupled with individual interviews was used to assess participants' NOS views before and at the conclusion of the course.
Keywords; nature of science, concepts, flashback, non-implicit attempt-oriented approach

Introduction

The majority of participants held naive views of the target NOS aspects at the beginning of the study. During the first week of class, participants were engaged in specially designed activities that were coupled with explicit NOS instruction. Throughout the remainder of the course, participants were provided with structured opportunities to flashback on their views of the target NOS aspects. Post-instruction assessments indicated that participants made substantial gains in their views of some of the target NOS aspects. Less substantial gains were evident in the case of the subjective, and social and cultural NOS. The results of the present study support the effectiveness of explicit, flashback NOS instruction. Such instruction, nonetheless, might be rendered more effective when integrated within a conceptual change approach.

The goal of helping students develop adequate conceptions of nature of science (NOS) has been agreed upon by most scientists, science educators, and science education organizations during the past 85 years (Angeil,P.,& Lederman, 2010). At present, despite their varying pedagogical or curricular emphases, agreement among the major reform efforts in science education [American Association for the Advancement of Science (AAAS), 2009, 2013; National Research Council (NRC), 2006] centers on the importance of enhancing K –12 students' conceptions of NOS. However, the achievement of this long-espoused goal has been met with little success. Research has consistently shown that students' NOS views are not consistent with contemporary conceptions of the scientific endeavor (Duschel, 2009; Lederman,2010).

Starting in the early 1960s, several units, courses, and curricula (e.g., Annita, 2010; Klopfer & Cooley, 2009) that were designed to address NOS understandings significantly increased students' scores on NOS assessment instruments. These curricula used history and philosophy of science and/or instruction that emphasized NOS to foster adequate conceptions among students. Also, some of the inquiry-oriented, laboratory-centered curricula of the 1960s were shown to enhance students' NOS views (e.g., Cripp, 2008; Sorensen, 2006). These units, courses, and curricula, however, denied the importance of the role of teachers: Researchers concluded that student gains were independent of the teachers' understandings of NOS (Lederman,2010).

Later studies, however, came to cast doubt on such results and conclusions. When variables such as pretesting, teacher experience, and student prior knowledge were controlled for, con-fusing results emerged. The developed units and curricula seemed to give different results with different teachers (e.g., Kleinman, 2008; Yager & Wick, 2006). Moreover, compared with traditional science courses, several of the 1960s curricula were shown to be ineffective in advancing students' understandings of NOS (e.g., Duryea, 2009; Jungwirth, 2002; Trent, 2008; Troxel, 2011). Researchers started to realize the role of teachers as the main intermediaries of the science curriculum (Bush & Clarke, 1999). More studies came to support the claim that teachers' understandings, interests, attitudes, and classroom activities affect student learning to a large extent (e.g., Merill & Butts, 2011; Ramsey & Howe, 2011). This realization turned researchers' attention toward assessing teachers' conceptions of NOS.

Irrespective of the assessment instruments used, studies repeatedly indicated that high school and secondary science teachers' views were not consistent with contemporary conceptions of NOS (e.g., Angeil.P & BouJaoude, 2007; Anna, Hamilton, & Linder, 2009; Black, 2011; Clark & Straus, 2011, 2002; Kimball, 2007–68; King, 2010; Koulaidis & Og-born, 2011; Pomeroy, 2013). In some cases, teachers scores on those assessment instruments were not different from or lower than their students scores (e.g., Miller, 2009). Science teachers held naive views of several important aspects of NOS. A significant proportion of teachers, for example, did not endorse the tentative nature of scientific knowledge. Rather, they believed that science is a body of knowledge that has been "proven" to be correct (Anna et al., 2009).

Many teachers held naive views of the meaning and function of scientific theories and laws (Black, 2011) and/or ascribed to a hierarchical view of the relationship between the two, whereby theories become laws with the accumulation of supporting evidence (Angeil.P & BouJaoude, 2007). A majority of teachers still held a positivistic, idealistic view of science (Pomeroy, 2013); others believed in a universal stepwise procedure, "The Scientific Method," for "doing science," thus dismissing the creative and imaginative nature of the scientific endeavor (Angeil.P & BouJaoude, 2007; Lederman, 2010). In an attempt to mitigate this state of affairs, research efforts were directed toward enhancing science teachers' conceptions of NOS.

Improving Science Teachers' Views of NOS In their comprehensive review of the attempts undertaken to improve science teachers' conceptions of NOS, Angeil.P and Lederman (2010) noted that these attempts used one of two general approaches. The first approach was implicit and advocated by science educators such as Gadget, Rubbers, and Franz (2007), Haakon and Penteck (2003, 2005), Lawson (2009), and Rowe (2009). This approach suggests that an understanding of NOS is a learning outcome that can be facilitated through science process skills instruction, science content coursework, and doing science. Researchers who adopted this implicit approach used science process skills instruction and/or scientific inquiry activities (Bago, Betty, & Lamb, 2007; Riley, 2010; Trembath, 2009) or manipulated certain aspects of the learning environment (Haakon & Penteck, 2003, 2005; Scharmann, 2009; Scharmann & Harris, 2010; Spears & Zollman, 2007) in their attempts to enhance teachers' NOS conceptions. The implicit approach, however, was devoid of any explicit or flashback components related to NOS.

The second approach was explicit and advanced by educators such as Billet and Harry (2005), Kimball (2007–2008), Klopfer (2004), Lavach (2011), Robinson (2008), and Rutherford (2004). Researchers who adopted this approach (Annol, 1988; Billet & Harry, 2005; Clark & Straus, 2011, 2002; Jason, 2011; Lavach, 2011; Ogunniyi, 2003) used elements from history and philosophy of science and/or instruction geared toward the various aspects of NOS to improve science teachers' conceptions.

When the reviewed studies, which were mostly quantitative in nature, were examined on the basis of the statistical models that were employed and the numerical gains that were reported, Angeil.P and Lederman (2010) concluded that the explicit approach was generally more "effective" in fostering "adequate" conceptions of NOS among prospective and practicing science teachers. Angeil.P and Lederman noted that two interrelated assumptions seemed to underlie the implicit approach and compromise its effectiveness. The first assumption depicted attaining an understanding of NOS to be an "affective" as compared to a "cognitive" learning outcome. This assumption entailed a second one: the assumption that learning about NOS would result as a by-product of engagement in science process-skills instruction or science-based activities that lacked any explicit references or flashback components related to NOS. Nonetheless, when the reviewed attempts, both implicit and explicit, were scrutinized in terms of the resultant science teachers' NOS understandings, Angeil.P and Lederman concluded that much is still desired in terms of fostering among science teachers conceptions of NOS that would enable them to convey to students more adequate views of the scientific endeavor.

Most of these attempts to improve science teachers' NOS views were undertaken in the context of pre-service high school or secondary science methods courses and in-service workshops/ institutes. However, research on situated cognition (e.g., Bush, Collins, & Duguid, 2011) and the transfer of learning in relation to teacher preparation (e.g., Lanier & Little, 2006) suggests that education courses might not provide the optimal context for promoting teachers' views of NOS: Pre-service and novice teachers consistently demand one-to-one correspondence between the content of education courses and anticipated actual teaching content/settings (Lanier & Little, 2006). Such demand is also evident in the case of pre-service teachers and NOS instruction (Angeil.P et al., 2010). We believe that developing science teachers' views of NOS would be achieved best in the context of science content courses. An explicit, flashback approach to NOS instruction embedded in the context of learning science content would not only facilitate developing science teachers' NOS views, but might go a long way in helping teachers trans-late their NOS understandings into actual classroom practices. However, in addition to their experiences with school science, teacher candidates mostly learn science content in traditional courses offered by various disciplinary college departments.

As such, in the absence of any systemic reform of science teaching, especially at the college level, it is highly likely that teacher candidates will continue to join teacher education programs with naive views of the scientific enterprise (Lederman & Latz, 2005; Stofflett & Stoddart, 2011). It follows that science educators need to continue their efforts to develop and assess the effectiveness of various instructional approaches aimed at promoting science teachers' views of NOS in the context of education courses, particularly science methods courses, in which they come in contact with prospective teachers. In this regard, it cannot be overemphasized that we recognize that science methods courses might not be the optimal context for developing science teachers' NOS views. However, in many cases, they are the only available context.

The purpose of the present study was to assess the effect of a set of activities developed by Lederman and Angeil.P (2010), and implemented within an explicit, flashback approach, on pre-service high school teachers' conceptions of NOS. The specific questions that guided this research were: (a) What meanings do pre-service high school teachers ascribe to some aspects of NOS? and (b) What is the impact, if any, of using a flashback, explicit, attempt-based approach with pre-service high school teachers' views of these aspects of NOS? Before proceeding to describe the methodology undertaken in the present study, it is important to elucidate our view of NOS and the aspects of this multifaceted construct that were emphasized in this investigation.

NOS

Typically, NOS refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 2010). These characterizations nevertheless remain fairly general, and philosophers of science, historians of science, sociologists of science, and science educators are quick to disagree on a specific definition for NOS. Such disagreement, however, should not be surprising given the multifaceted and complex nature of the human endeavor we call science. Moreover, similar to scientific knowledge, conceptions of NOS are tentative and dynamic: These conceptions have changed throughout the development of science and systematic thinking about its nature and workings (Angeil.P & Lederman, 2010).

However, at one point in time and at a certain level of generality, there is a shared wisdom (even though no complete agreement) about NOS among philosophers, historians, sociologists, and science educators. For instance, it would be hard to reject the theory-laden nature of scientific investigations or to defend a deterministic/absolute or empiricist conception of NOS in the 1990s. Moreover, at such a level of generality, some important aspects of NOS are virtually noncontroversial. Such NOS aspects have been advanced in recent reform documents in science education, such as Science for All Americans (AAAS, 2009, especially Chapter 1) and National Science Education Standards (NRC, 2006, especially Chapter 6).

In the present study, seven of these aspects that we believe are accessible to K–12 students and relevant to their daily lives were adopted and emphasized (also see Angeil.P et al., 2010). These aspects are that scientific knowledge is tentative (subject to change), empirically based (based on and/or derived from observations of the natural world), subjective (theory-laden), partly the product of human inference, imagination, and creativity (involves the invention of explanation), and socially and culturally embedded. Two additional important aspects are the distinction between observations and inferences, and the functions of and relationships between scientific theories and laws.

Method

The present study was interpretive in nature (Strauss & Corbin, 2009) and focused on the meanings that participants ascribed to the emphasized NOS aspects. Data collection was continuous and spanned the whole semester in which participants were enrolled in the investigated high school science methods course.

Participants

Participants were 50 students enrolled in two sections of a high school science methods course offered in a midsized Western state university. Twenty-five undergraduate students (23 female and 2 male) were enrolled in the first section and 25 graduate students (22 female and 3 male) were enrolled in the second. The undergraduates' ages ranged between 23 and 43 years, with a median of 28 years, whereas the graduates' ages ranged between 25 and 52 years, with a median of 32 years. Undergraduate students were seeking a bachelors degree in high school education; graduate students were working toward a Master in Teaching (MIT) degree in high school education. Both undergraduate and graduate participants were in the first year of their respective programs. The greater majority of the undergraduate participants (90%) had completed 10 –16 science credit hours. Most of the graduate students (85%) had completed 12–15 science credit hours. Only two of the graduate participants held bachelors degrees and had completed more than 100 science credit hours. Thus, with the exception of these latter two students, the science backgrounds of both undergraduate and graduate participants were not substantially different. Moreover, none of the participants, graduate or undergraduate, had formal course-work in history or philosophy of science.

Context of the Study: A High School Science Methods Course

The same instructor (the first author) taught both sections of the high school science methods course (3 credit hours) in which participants were enrolled. The two sections were similar in structure and requirements. Classes were held weekly in 3-h blocks throughout the semester.

The course aimed to help pre-service high school teachers develop (a) a theoretical framework for teaching science at the high school level, (b) a repertoire of methods for teaching science, (c) favorable attitudes toward science and science teaching, and (d) deeper understandings of some science content area.

The same readings, activities, and assignments were presented and undertaken in the two course sections. Pre-service teachers were assigned weekly readings that were mostly pedagogical in nature. They were also engaged in weekly hands-on/minds-on activities. These in-class activities were content-based explorations designed to help pre-service teachers experience a variety of teaching methods and reinforce their understandings of key science concepts. The course assignments included an in-depth study of a science content area emphasized in Benchmarks for Science Literacy (AAAS, 2013) and chosen by pre-service teachers. Each participant then inter-viewed an high school student to elicit his or her ideas about the target science content area and presented the interview findings to the rest of the class. Each pre-service teacher also submitted a paper illustrating the understandings that he or she acquired as a result of studying the target content area, and contrasting those understandings with corresponding ideas elucidated by the interviewed high school student. Next, pre-service teachers wrote a series of three lesson plans specifically designed to address the interviewee alternative ideas or misconceptions. The lesson plans were to be designed with a conceptual change pedagogy (Posner, Strike, Haakon, & Gert-zog, 2009) in mind. In addition, pre-service teachers wrote weekly flashback papers on the assigned readings and tasks.

Data Collection and Instruments

An open-ended questionnaire in conjunction with semi-structured interviews was used to assess participants' views of the target aspects of NOS. All participants were administered the questionnaire before and at the conclusion of the course. In addition, a total of 40 participants (20 from each course) were selected for interviewing. In each course section, half of these participants [10 students (40%)] were randomly chosen for pre-instruction interviews; the other half was interviewed at the conclusion of the study. The use of an open-ended questionnaire was intended to avoid the problems inherent in the use of standardized forced-choice paper and pencil NOS assessment instruments. These instruments are based on the problematic assumption that the meanings that respondents ascribe to an instrument items, and the reasons behind their choosing certain responses correspond to those of the instrument developers and/or researcher(s). Moreover, because they were of the forced-choice type, these instruments often end up imposing a certain view of NOS on respondents (Lederman, Wade, & Bell, 2010). In contrast, open-ended items allow respondents to elucidate their own views regarding the target aspects of NOS and the reasons that underlie their views (Lederman, 2010; Lederman & O'Malley, 2009). The seven-item open-ended questionnaire used in the present study (Appendix) was previously used and validated by Angeil.P et al. (2010) and Bell, Lederman, and Angeil.P (2010).

Nonetheless, given that the present study was concerned with the meanings that participants ascribed to the seven emphasized aspects of NOS, it was imperative to avoid misinterpreting participants' responses to the questionnaire. As such, individual semi-structured interviews were used to establish the validity of the questionnaire by insuring that the researchers' interpretations corresponded to those of participants. The interviews also aimed to generate in-depth profiles of participants' NOS views. During the interviews, which were conducted by the first author, participants were provided with their pre- or post-instruction questionnaires and asked to read, explain, and justify their responses. Follow-up questions were used to clarify participants' responses and further probe their lines of thinking. All interviews, which typically lasted about 45 min, were audio-taped and transcribed for analysis. Finally, student flashback papers and a detailed researcher log served as additional sources of data.

Intervention

During the first 6 h in the course, the instructor engaged participants in 10 different activities that explicitly addressed the seven target aspects of NOS. Detailed descriptions of these activities can be found elsewhere (Lederman & Angeil.P, 2010). Two of the activities addressed the function of and relationship between scientific theories and laws. Two other activities ("Tricky tracks" and "The whole picture") addressed differences between observation and inference, and the empirical, creative, imaginative, and tentative nature of scientific knowledge. Four other activities ("The aging president," "that's part of life!" "Young? Old?" and "Rabbit? Duck?") targeted the theory-ladenness and the social and cultural embeddedness of science. Finally, two black-box activities ("The tube" and "The cubes") were used to reinforce participants' understandings of the above NOS aspects. The activities were purposefully selected to be generic in nature (not content specific) given the participants' limited science content backgrounds. Each attempt was followed by a whole-class discussion that aimed explicitly to highlight the target aspects of NOS and involve students in active discourse concerning the presented ideas.

This initial attempt-based explicit NOS instruction was intended to provide participants with a NOS framework by introducing and, in a sense, sensitizing them to the target NOS aspects. These aspects became a theme that permeated the remaining course activities. Through-out the remainder of the course, participants were provided with structured and unstructured opportunities to think, both orally and in writing, on various aspects of NOS as they arose during course activities or as they related to course readings. Whether students were engaged in learning science content or pedagogy, they were often asked to think about how that content or those teaching strategies were related to NOS. This flashback component of the intervention aimed to help participants articulate and elaborate their acquired NOS understandings and apply those understandings in various contexts. The instructor kept a detailed log of all these flashback opportunities, examples of which are provided in the following two sections.

Classroom Discussions

Participants were often asked to relate the NOS aspects discussed at the outset of the intervention to other course science-content and pedagogy topics. For ex-ample, to contextualize earlier discussions of scientific theories, the instructor asked participants to examine and comment on the Benchmarks definition of evolution as a scientific theory (AAAS, 2013, p. 122). The ensuing discussion focused on the explanatory function of evolutionary theory and its role in generating and guiding several fruitful biological research pro-grams. In the context of discussing assessment and evaluation practices and techniques, participants were asked whether and how NOS was related to the assessment of high school students' science content knowledge. The ensuing discussion in the graduate section of the course high-lighted the distinction between observation and inference as evident in the following excerpt:

> Student 1: Assessment is only a picture of what students might know, not . . . what they actually do know. It is like science. You are looking at pieces of evidence, trying to draw conclusions and then infer what the evidence means about what the students know about a given concept.
> Instructor: That is an interesting idea. It does relate to our discussions on NOS. Could anyone add to this discussion?
> Student 2: Yeah. It is like the "tubes" attempt [one of the activities presented in the first 2 weeks of class]. With a lot of variety of assessments you can get a better picture of what the student knows than with only one method of assessment. With the "tubes" attempt, if you pull only one string you will have less of an idea of what is inside the tube than if you pull all of the strings and see what happens.

In the undergraduate section of the course, the issue of the scientific method was brought up in the context of discussing a course reading related to assessing science process skills. The instructor raised the following questions: "Do you think there is a scientific method that includes all of those process skills in a particular order? Can we use this scientific method to assess students' mastery of process skills?" These questions started students thinking about the distinction between the finished products of science as they appear in professional journals and the actual work that scientists engage in during their daily activities:

> Student 1: That is how all the journal articles are written. Yes, there is definitely a scientific method.
> Instructor: Do you mean that this "method" is an actual step-by-step procedure just as is described in scientific publications? When you "do science" do you always ask a question, then observe, then hypothesize, then design an experiment, then collect data, then draw your conclusions in that order?
> Student 1: No, not really. It is more mixed up in order when you do it. When you write it up you kind of have to "figure out" a logical way to present what you did and then you can probably get to publish it.
> Student 2: Probably you do observations and all those things, but they are in different orders. Then when you write it up is when you put it in the order the magazine [journal] wants.

In the context of discussing unifying themes from the Benchmarks, the notion of models was brought up (AAAS, 2013, pp. 267–270). The instructor asked the undergraduates whether this discussion was related in any way to earlier NOS discussions. Students referred to the tubes attempt in the attempt to explain the nature of models and their importance in science:

> Student 1: It is like the tube attempt.
> Instructor: How so?
> Student 1: You are seeing the evidence when you pulled on the strings of the tube and the evidence showed you how you could build your tube to match the real thing. You don't really know what the real thing is, but can approximate it through the model. If the model works like the real thing, it is a good model . . . the model can help explain what you are studying.

Children's literature books were often shared with participants, and the question "What does this book have to do with science?" was almost always used to prompt discussions about NOS.

For instance, at about the midpoint of each course section, Earthmobiles as Explained by Professor Xargle (Willis, 2010) was read to the class. This book discusses transportation on Earth from the viewpoint of aliens.

The instructor asked, “Why would I read this book to you? What does this book have to do with science?” The ensuing discussion with students focused on the empirical and theory-laden NOS. Graduate participants noted that the nature of one’s prior knowledge or perspective that is brought to bear on evidence does impact the conclusions or interpretations with which one ends up. Nonetheless, such conclusions or interpretations need to be consistent with one’s observations:

Student 1: It talks about different viewpoints.
Student 2: Yes, it is like drawing conclusions based on your own viewpoint.
Student 3: It is good for sharing how things can be described and interpreted from different viewpoints.
Instructor: To me it is like science because the aliens are taking the evidence of what they observe and interpreting through their own lens. They are drawing conclusions and presenting them based on their prior knowledge and their interpretations from that evidence and knowledge. They don’t know for certain if their ideas/interpretations are correct, but they are reasonably sure that their conclusions, based on their observations, make sense.
Student 4: This is another nature of science thing again.

These discussions might help illustrate the importance of explicit prompts to get students to think about and reflect on different issues related to NOS. Without such prompts, these discussions, which got students involved in discourse about NOS, were not likely to have taken place. Students’ involvement in such discussions, we believe, is crucial for providing them with opportunities to clarify their ideas about NOS for themselves in the first place, and for others in the second place. It is noteworthy that toward the beginning of the course, these discussions were almost exclusively dependent on explicit prompts from the instructor. However, as the term progressed, students began to recognize on their own elements of NOS that were embedded in various course activities or readings. On several occasions, students themselves initiated whole-class discussions by posing questions. At this stage, the instructor’s role shifted from prompting discussion about NOS to facilitating the discussion, providing focus, and helping participants to come to some sort of closure.

Written Flashbacks. In addition to verbal discussions, participants were required to respond in writing to two flashback prompts related to NOS. For the first flashback paper, participants were asked to read the prologue for Penrose’s (2011) Shadows of the Mind: A Search for the Missing Science of Consciousness and answer the following questions: “Do the ideas in this reading fit our discussions of NOS? If yes, how? If no,why? In your discussion try to focus on the elements of tentativeness, creativity, observation versus inference, subjectivity, relationships of theory and law, and social and cultural embeddedness of science.” This short reading is a dialogue between young Jessica and her father. The father, a scientist, goes into a cave to collect some plant specimens and Jessica goes along. While inside, Jessica wonders what would hap-pen if she, her father, and others got trapped inside the cave. Eventually, Jessica comes to ask, “How could I know what the real world outside was like? Could I know that there are trees in it, and birds, and rabbits and other things?” (Penrose, 2011, p. 2). The ensuing conversation focuses on how we know and how valid our knowledge is, as Jessica’s father tries to explain to her how much they could learn about the outside world just by observing whatever shadows that might form on their cave walls. Participants’ responses to this prompt focused on the social, theory-laden, and tentative NOS, and the distinction between observation and inference as evident in the following excerpts from student papers:

Jessica and her father’s theories about the outside world could never be more than tentative. . . . This is the case in science today. Since we cannot directly see the atom or black holes, our inferences about these concepts are tentative even though they are as reason-able as possible given the evidence. (G13, first flashback paper).

One of the aspects of the nature of science that this story illustrates is subjectivity. We interpret things based on what we know. Because if we were born in a cave we would have to infer what was outside the cave from observations, we might not really know what is there, though it would make sense to us. Much of our scientific knowledge today seems to me to come from observing the “shadows on the wall” and maybe what we think we know is really way off. (U19, first flashback paper).

A few participants were successful in mapping relationships among all seven emphasized aspects of NOS and the dialogue between Jessica and her father. One such student, a graduate, chose to represent these relationships in the form of a highly integrated semantic map (Figure 1).

For the second flashback paper, participants watched the Bill Nye the Science Guy “Pseudoscience” episode and responded to the following questions: “Do the ideas that Bill Nye shared in the ‘Pseudoscience’ episode fit our discussions of NOS? If yes, how? If no, why? In your discussion try to focus on the elements of tentativeness, creativity, observation versus inference, subjectivity, relationships of theory and law, and social and cultural embeddedness of science.”

Again, in their flashback papers, students focused on the tentative and empirical nature of scientific knowledge and the roles of observation versus inference in the generation of scientific knowledge, as evident in the following representative quotes:

The episode showed that new evidence can change our view about what we know about science. Bill Nye focused on observation vs. inference, because he pointed out how with-out direct observation inferences could really be wrong, like with thinking crop circles are created by UFOs. (U18, second flashback paper).

The show really discussed the difference between science and pseudoscience. Real science can be tested. Pseudoscience is not testable. (G5, second flashback paper).

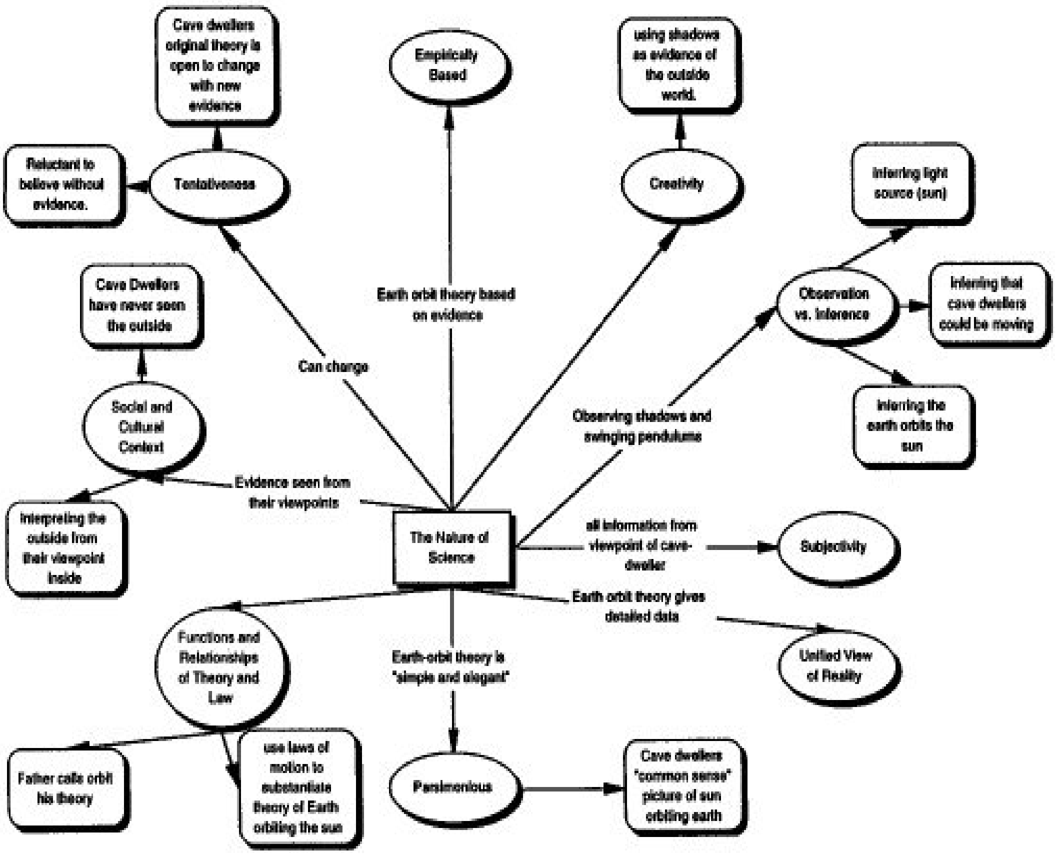

Figure 1. This integrated semantic map is taken from a pondering paper to the Penrose (2011) reading. It represents one participant's attempt to map relationships between the reading and the target NOS aspects.

Data Analysis

The second and third researchers analyzed the data. This approach was undertaken because the first researcher was the instructor of the investigated course, and consequently she might have perceived the data to be partially evaluative.

The questionnaires and corresponding interview transcripts of the 40 interviewed participants were separately analyzed and compared for the purpose of establishing the validity of the open-ended NOS questionnaire. The questionnaires were thoroughly read and searched for initial patterns. The same process was repeated with the corresponding interview transcripts. The patterns that were generated from the independent analysis of the questionnaires and interviews were compared and contrasted. This analysis indicated that the profiles of participants' NOS views as derived from the NOS questionnaires were faithful to participants' views as expressed and elaborated during individual interviews.

Next, all NOS questionnaires were analyzed to generate pre- and post-instruction profiles of participants' views of NOS in the two course sections. In this analysis, each participant was treated as a separate case. Data from each questionnaire were used to generate a summary of each participant's views. This process was repeated for all the questionnaires. After this initial round of analysis, the generated summaries were searched for patterns or categories. The generated categories were checked against confirmatory or otherwise contradictory evidence in the data and were modified accordingly. Several rounds of category generation, confirmation and modification were conducted to reduce and organize the data satisfactorily. Moreover, analyses of participants' reaction papers were used to corroborate or otherwise modify the views derived from analyzing the NOS questionnaires. Finally, pre- and post-profiles were compared to assess changes in participants' views. These changes were compared across the two course sections.

Results

The following sections elucidate participants' pre-instruction and post-instruction views of the target aspects of NOS. In these sections, a coding system is used to refer to participants. The codes "U" and "G" refer to undergraduate and graduate participants, respectively. The number following a "U" or "G" refers to an individual participant. Table 1 presents a summary of results from the study. The table shows the percentage of students who held adequate views of NOS before and after instruction for each of the elements emphasized in the course.

Pre-instruction NOS Views

Some participants held adequate views of some aspects of NOS at the beginning of the study. An examination of the second and fourth columns in Table 1 indicates that undergraduate and graduate participants' pre-instruction views of the distinction between observation and inference and the relationship between theories and laws, as well as their views of the subjective, and social and cultural NOS were very similar. More graduate participants, however, held adequate views of the empirical and tentative NOS, whereas more undergraduates held adequate conceptions of the creative and imaginative NOS. The lack of substantial differences between undergraduate and graduate participants' NOS views is consistent with research findings that indicate that learners' NOS views are not significantly related to their science content knowledge (Billet & Harry, 2005; Clark & Straus, 2011, 2011, 2002; Kimball, 2007– 68;Wood, 2009).

Nonetheless, the majority of participants, both graduate and undergraduate, harbored naïve views of one or more of the seven target aspects of NOS. As evident in the wide range of percentages (0–56%) of participants with adequate views of the target NOS aspects (Table 1,Columns 2 and 4), participants' views lacked consistency. None of the participants held adequate views of all seven investigated NOS aspects at the beginning of the study. This compartmentalized and fragmented nature of participants' views of NOS was not unexpected (Angeil.P, 2010) given that before this investigation, the majority of these participants were not given opportunities to think about and clarify their conceptions of science as an enterprise.

Table 1

Percentage of participants with adequate views of emphasized aspects of NOS

	Undergraduate Student Views		Graduate Student Views	
NOS Aspect	Preinstruction	Postinstruction	Preinstruction	Postinstruction
Empirical	4	32	28	52
Tentative	8	52	16	72
Creative and Imaginative	24	80	16	
40				
Subjective (theory-laden)	32	52	44	52
Social and Cultural	56	80	56	72
Observation versus Impact	40	80	48	84
Theories and Laws	4	48	0	56

The following sections elucidate participants' pre-instruction NOS views. As noted above, some participants held adequate views of the target NOS aspects at the beginning of the study. The quotes presented below, however, are meant to illustrate views that were considered naive. Quotes illustrating more adequate views will be presented in a later section.

Observation Versus Inference

In response to the question of how certain are scientists about the structure of the atom and the evidence used to derive this structure, more than half of all participants, both graduate (52%) and undergraduate (60%), were not able to adequately articulate the distinction between observation and inference. These participants failed to realize the role of inference in deriving scientific constructs. For them, seeing was knowing. Indeed, these participants dismissed the inferential nature of atomic structure and noted that scientists were certain about the structure of the atom because they were able to observe atoms using high powered microscopes:

> You have to use your senses to be able to tell what anything is like. You have to see it, or use something that lets you see it, like in a special microscope you can see atoms. (U3, pre-questionnaire)
>
> Scientists can see atoms with high-powered microscopes. They are very certain of the structure of atoms. You have to see something to be sure of it. (G15, pre-questionnaire)
>
> In other words, these participants seemed to believe that scientists are able to find

about phenomena only if these are directly accessible to the senses.

Functions of and Relationship between Scientific Theories and Laws

With the exception of one undergraduate student, all participants explicated inadequate views of this NOS aspect. Participants failed to recognize the well-substantiated nature of scientific theories, and when responding to the question "Why we bother learn about scientific theories?" participants did not allude to the explanatory function of theories or their role as guiding frameworks for research.

Simply, for almost all participants, a scientific theory represented "a guess or a question that has not been proven or

disproven by experiments" (G9, pre-questionnaire). This latter notion is most likely related to the vernacular use of the term theory.

Participants also subscribed to another well-documented misconception regarding the relationship between scientific theories and laws (e.g., Angeil.P et al., 2010; Hudson & Rub, 2010). They did not seem to realize that theories

and laws are different kinds of scientific knowledge and serve different functions, and that one does not become the other. They believed in a hierarchical relationship between theories and laws whereby theories become laws when they are proven, as evident in the following representative quotes:

> Laws started as theories and eventually became laws after repeated and proven demonstration. . . . Perhaps the difference between a law and a theory is the degree of proof???(G15)
>
> A scientific law is a theory that has been proven over and over by different scientists.(U13)

These quotations indicate that participants subscribed to the inductive fallacy: They seemed to believe that a scientific hunch (a theory) could be proven to be correct with the accumulation of supporting experimental evidence. Moreover, given this belief, many participants seemed to think that laws are absolute and not subject to change. Indeed, when asked about what they meant by the phrase "laws are proven," most interviewees answered, "When a scientific law has been proven repeatedly, it means it has not changed since it was discovered . . . [and] I don't think it will change in the future" (G21, pre-interview).

Empirical and Tentative NOS

Only one undergraduate participant (4%) and seven graduate participants (28%) expressed adequate views of the empirical NOS. These participants noted that science is different from other disciplines because scientific claims should be consistent with empirical observations. The greater majority of participants, however, did not include observations of natural phenomena as a characteristic factor that sets science apart from other disciplines, such as art. These participants mostly noted that science is characterized "by a method for doing things" (U16, pre-questionnaire), as a way "to prove theories" (G24, pre-questionnaire), or by its being a study of "life" or "everything around us."

Similarly, the greater majority of participants (92% of undergraduates and 84% of graduates) did not hold adequate views of the tentative NOS. As noted above, many participants believed that scientific laws are proven or absolute and not subject to change. Many participants noted that scientific theories do change. However, these participants attributed theory change solely to new discoveries brought about by advances in technology, thus excluding the role of reinterpreting extant data or of new ideas in engendering theory change:

> Yes, theories can change after they are developed because of the new technology. An example would be the microscope. Several theories have changed because of high-powered microscopes. (U17, pre-questionnaire)
>
> Theories do change. As technology advances we get more information, and can change the theory. (G23, pre-questionnaire)

Moreover, further probing during interviews indicated that participants seemed to believe that theories do not change in the sense of being rejected or replaced. Rather, they believed that theories are refined or expanded. Many interviewees noted that "Yes, they [theories] do change. . . . Scientists keep on adding to our theories so that they become better as more discoveries are made" (G14, pre-interview). Nonetheless, as evident in these quotations, most participants believed that some theories will eventually be proven and change into laws, in which case they are not liable to change.

Creative and Imaginative NOS

Most participants (76% of undergraduates and 84% of graduates) did not demonstrate adequate understandings of the role of human inference, imagination, and creativity in generating scientific claims. As noted above, participants believed that seeing is knowing, and did not seem to appreciate the imaginative and creative work involved in deriving patterns from data or constructing scientific models and theories. Although participants indicated that scientists use "creativity" in their work, the term was used to refer to scientists' resourcefulness or ability to come up with good designs or problem solve, rather than to indicate that science involves the invention of theories and explanations:

> Scientists use creativity to help them solve problems. Like to build a car that will sell better than another model because people like the design better. (U23, pre-questionnaire)

When participants granted that theory generation might involve creativity, they noted that scientists still have to follow the scientific method to ensure their objectivity:

> A good scientist must be creative to design a good experiment. . . . The scientist might be imaginative in coming up with a theory, but it must be through the scientific method so they stay objective. (G5, pre-questionnaire)

Moreover, when participants admitted a role for imagination and creativity in science, they restricted this role to the design stages of investigations. They failed to recognize that scientists use their imagination and creativity throughout scientific investigations, especially when interpreting data and inventing explanatory systems to explain those data. Participants noted that it was not acceptable or desirable to use creativity or imagination when interpreting data. Such use, they continued, would compromise the objectivity of scientists:

> A scientist only uses imagination in collecting data. . . . But there is no creativity after data collection because the scientist has to be objective. (G24, pre-questionnaire)

Subjective and Social and Cultural NOS

About one half of the participants failed to recognize that scientists' training and disciplinary backgrounds, their theoretical commitments, philosophical assumptions, prejudices and preferences, as well as the social and cultural contexts in which they live do affect their work. Alternatively, these participants believed that science was an objective endeavor and that scientists were detached from their work:

> Scientists are very objective because they have a set of procedures they use to solve their problems. Artists are more subjective, putting themselves into their work. (G17, pre-questionnaire)

As evident in this quotation, this "objectivity" is guaranteed by the use of a "set of procedures" or "the scientific method." Indeed, the belief that scientists use a single scientific method or other sets of orderly and logical steps characterized the responses of a large majority of participants:

> Science deals with using a good method so we can duplicate our results. That way we know we have the right answer. It is very exacting. (G3, pre-questionnaire).Well, yeah. They [scientists] do use a specific method. . . . The scientificmethod starts by observations, then coming up with a hypothesis and doing an experiment to test it. If you get the same result over and over and over, then you become sure that it works. (U8, pre-interview)

The lack of appreciation of the role of theories and disciplinary commitments in influencing scientists' activities and, in particular, their interpretation of data, and of the role that other social and cultural factors might play in this regard was evident in participants' responses to the last item on the NOS questionnaire (see Appendix). This item presented participants with a scientific controversy and asked them to explain how was it possible for scientists to reach different conclusions starting from the same set of data. More than one half of all participants attributed the controversy solely to the lack of data and dismissed the possible impact of the aforementioned factors. These participants believed that once scientists obtain all the data, they are oriented to come to the same conclusion and the controversy would be resolved:

> We don't know enough information yet to come to one conclusion about anything. Once we get enough information we will agree on why things are the way they are. (U12, pre-questionnaire)
>
> It is impossible to observe and measure the universe in its totality. We can only observe and measure part of the universe. If we could do more, we would have a better idea, and people would have similar conclusions. (G23, pre-questionnaire)

Post-instruction NOS Views

An examination of Table 1 (Columns 3 and 5) indicates that substantially more participants held adequate views of the target aspects of NOS at the conclusion of the study. With the exception of views related to the subjective, creative, and imaginative NOS, where undergraduates showed relatively more gains, changes in undergraduate and graduate participants' views were comparable. However, the observed changes were not consistent across the investigated NOS aspects. Changes in participants' views were particularly pronounced with regard to the tentative NOS, the distinction between observation and inference, and the functions of and relationship between

scientific theories and laws. Changes were also evident in participants' views of the empirical, subjective (theory-laden), and social and cultural NOS. These changes nonetheless were less pronounced.
The following sections elucidate participants' post-instruction NOS views. Some participants held inadequate views of the target NOS aspects at the conclusion of the study. The quotations presented below, however, are meant to illustrate views that were considered adequate or sophisticated. Quotes illustrating inadequate or naïve views were highlighted in the Pre-instruction NOS Views section above.

Observation Versus Inference
Compared with 40% of undergraduates and 48% of graduates who expressed adequate views of the distinction between observation and inference at the beginning of the study, 80% and 84% of undergraduate and graduate participants, respectively, elucidated adequate views of this aspect of NOS at the conclusion of the study. These participants seemed to appreciate the inferential nature of atomic structure. On exiting the course, substantially more participants used terms such as idea or model of the structure of the atom in their attempts to explain how this structure was derived. As evident in the following representative quotations, participants noted that only indirect evidence could be used to construct models of atomic structure:

Scientists predict how certain atoms will act assuming a certain structure. Then experiments are performed with instrumentation to collect information. The data is analyzed and if seen to uphold the idea of the structure, the idea that an atom is structured in that way is supported. Scientists will infer they are right. (U21, post-questionnaire)

> Since atoms are much too small to see, scientists would have had to use indirect means to figure out what atoms look like. They did experiments and came up with models that would explain the way matter behaved, did more experiments, and adjusted the models to be consistent with what they learned about the way matter behaved. (G2, post-questionnaire)

Functions of and Relationship between Scientific Theories and Laws
As noted earlier, al-most all participants endorsed a hierarchical view of the relationship between theories and laws at the beginning of the study. At the conclusion of the course, about half of all participants (48% of undergraduates and 56% of graduates) adopted the more adequate view that scientific theories and laws were different kinds of scientific knowledge. These participants noted that whereas scientific theories are inferred explanations for observable phenomena, scientific laws state, identify, or describe relationships among such phenomena:

> Scientific theory is the inferred explanation for observable phenomena. Scientists infer explanations by observing. Scientific law is the statement of what you observe happening.(U8, post-questionnaire)
> A scientific law describes something that happens in nature. A theory is an attempt by scientists to explain why nature is the way it is. (G18, Post-questionnaire)

The post-instruction responses of participants also indicated more adequate views of the function of scientific theories. A majority of these participants (about 50%) noted that theories "are powerful ways to explain natural phenomena" (U22, post-questionnaire). Moreover, the responses of many participants (38% of all participants) indicated an appreciation for the role of scientific theories as guiding framework for future research efforts:

> Theory can provide a way to guide thinking. Theory sparks creative analysis and can open the door to further inquiry, discussion, questioning, and testing of a theory to see whether it is the best explanation for what is observed. (G11, post-questionnaire)

Empirical and Tentative NOS
Compared with 4% and 28% of undergraduate and graduate participants at the beginning of the study, 32% and 52%, respectively, of these participants expressed more adequate views of the empirical NOS at the conclusion of the course. These participants indicated that observations of the natural world set science apart from other disciplines such as the arts, as evident in the following representative quotation: "Scientists collect data to support their interpretation of the world. Artists just show their interpretation of the world" (G14, post-questionnaire). It is noteworthy that these latter participants did not subscribe to an empiricist view of science. Although they emphasized the primacy of evidence in scientific investigations, they still admitted a role for scientists' theoretical commitments and their larger social and cultural contexts in affecting and guiding such investigations (see section on Subjective, and Social and Cultural NOS below).

Substantial changes were evident in participants' views of the tentative NOS. Compared with 8% and 16% of undergraduate and graduate participants, respectively, at the beginning of the study, 52% and 56% of these participants elucidated more adequate views of the tentativeness of scientific knowledge at the conclusion of the course. Similar to their pre-instruction views, these participants noted that new information, discoveries, and technologies lead to expanding and refining scientific knowledge, as evident in the following representative quotation:

> Scientists create new information, learn new information, and discover new information, which leads to the conclusion that all scientific "knowledge" is a starting point for new knowledge. Scientists are always expanding on old knowledge and building new knowledge. (U23, post-questionnaire)

In their post-instruction responses, however, these participants also noted that new observations or better ideas might also lead to the outright rejection and abandonment of some scientific theories. These theories are then replaced withnew ones that have more explanatory power:

> Scientific theories frequently change. A theory is just our attempt to explain natural phenomena. A new observation or the results of a new experiment may reveal that the explanation doesn't "work" or fit the evidence, and scientists will alter or abandon the theory, or come up with different (but still plausible) theories to explain the event. (G2, post-questionnaire)

Also, substantially more participants elucidated the view that all scientific knowledge including theories and laws are subject to change, as evident in the following representative quotation:

> [The] nature of science, to "add to," "disprove," or "validate" theories generated. Everything in science is subject to change with new evidence and interpretation of that evidence.
>
> We are never 100% sure about anything because one piece of negative evidence will call a theory or law into question, and possibly cause a modification. (G9, post-interview)

Creative and Imaginative NOS

Twice as many undergraduate (80%) as graduate participants (40%) exited the course with better understandings of the role of creativity and imagination in science. These participants believed that science, like art, required creativity and imagination, as evident in the following representative quotation:

> Both science and art are created by humans' minds. Both reach their fullest expression only when the scientist or artist shares his/her creation with other human beings. However, science is based on evidence, whereas art is not. (G11, post-questionnaire)

About 40% of all participants no longer believed that creativity was only used in the initial stages of scientific inquiry, but that it was an integral part to all stages of scientific investigation. In addition, many of these participants used the term creativity in the sense of inventing theories and explanations rather than resourcefulness:

> Scientists use their imaginations in creating theories. . . . Scientists use the knowledge gained from their experiments and observations, but their creativity and imagination are also important in looking at the data and coming up with a conclusion or in developing a theory. (U11, post-questionnaire)

Subjective and Social and Cultural NOS

As evident in Table 1, little change was observed in participants' views of the subjective (theory-laden), and social and cultural NOS. On exiting the course, more than half of participants (52%) demonstrated adequate views of the theory-laden NOS (an increase of 20% and 8% for undergraduate and graduate participants, respectively). Similarly, about 75% of participants (an increase of 24% and 16% for undergraduate and graduate participants, respectively) demonstrated more adequate views of the social and cultural NOS. In general, these participants recognized that scientists' prior knowledge, personal backgrounds and viewpoints, as well as other human elements, affect the ways in which scientists interpret empirical evidence:

> Scientists are human. They learn and think differently, just like all people do. They interpret the same data sets differently because of the way they learn and think, and because of their prior knowledge. (U24, post-interview).
>
> The human element in analyzing and interpreting data leaves much room for varying views. . . . Individuals will have different natures, mental processes, and backgrounds. The interpretation of data is subject to the human element. (G23, post-questionnaire)

Discussion and Implications

Consistent with research on science teachers' views of NOS (e.g., Angeil.P & BouJaoude, 2007; Anna et al., 2009; Black, 2011; Clark & Straus, 2011, 2002; King, 2010; Pomeroy, 2013), participant pre-service high school teachers held naive views of many of the investigated aspects of NOS at the beginning of the study. Participants' views were also compartmentalized and lacked consistency; features which were expected given that learners are often not provided with opportunities to reflect on and clarify their views of NOS (Angeil.P, 2010). Moreover, undergraduate and graduate participants' views of the target aspects of NOS were not substantially different. This lack of difference could at least in part be attributed to the fact that participants' backgrounds were not substantially different. An examination of the participants' profile indicates that undergraduate and graduate participants did not differ substantially in their median ages, and science and history and philosophy of science back-grounds.

The results of this study indicate that the explicit flashback attempt-based approach to NOS instruction undertaken within the context of the investigated science methods course was effective in enhancing participant pre-service high school teachers' views. Participants made substantial gains in their understandings of the target aspects of NOS. However, as noted earlier, these gains were not consistent across those NOS aspects. Participants made relatively more gains in their understandings of the tentative, and creative and imaginative NOS, as well as the distinction between observation and inference, and the functions of and relationship between theories and laws. Less substantial gains were evident in the case of the subjective (theory-laden), and social and cultural NOS.

Consistent with constructivist arguments (e.g., von Glasersfeld, 2010, 2011), the differential gains in the understandings of the target nature of science aspects achieved by participants could be attributed to the interaction between participants' pre-instruction NOS views and NOS instruction. However, such differential gains could also be attributed to the fact that the desired understandings of the target NOS aspects are not equally accessible, or were not made so, to participants in the present investigation. Several representative quotes of participants' post-instruction views of the subjective (theory-laden), and social and cultural NOS were provided earlier. An examination of these quotations indicates that they are at best fairly general statements about the impact of human and social factors on scientific investigations. The subtleties of the impact of subjective, and social and cultural factors on the generation of scientific knowledge or the work of scientists are hard to convey or capture in the absence of rich and extensive contextualization, such as historical case studies of the development of some scientific construct or discipline. Given the nature and long agenda of the investigated course, it was not possible to present such extensive contexts. At best, a few brief examples from history of science were shared with participants. This might help explain why participants made relatively less substantial gains in their understandings of the theory-laden nature, and the social and cultural embeddedness of science.

However, despite the favorable changes that were evident in participants' views at the conclusion of the study, the profile of participants' post-instruction NOS views indicates that much is still desired in terms of enhancing their conceptions of the scientific endeavor. Many participants still held naive views of one or more of the target NOS aspects. Moreover, very few participants (10%) seemed to have developed a consistent framework for thinking about the various emphasized aspects of NOS. Indeed, very few participants demonstrated an integrated understanding of the target NOS aspects through making connections between those aspects, as was the case, for instance, with the student who constructed the semantic map shown in Figure1.

Some participants seemed to have internalized certain adequate views of NOS, such as that scientific knowledge is empirical, and reconciled them with other naive views, such as that every scientist is entitled to his or her own view of some natural phenomenon. These results indicate that a main concern of educators interested in enhancing science teachers' NOS views should be to provide teachers with opportunities to examine their views of NOS holistically and reconcile their views about the various facets of the multifaceted and complex scientific endeavor.

The results of this study are nonetheless consistent with research on alternative conceptions (Posner et al., 2009) and serve to show the tenacity with which learners hold on to their own views. After all, participants' views of NOS have developed over years of high school and secondary (and for graduate participants, college) education. It is unlikely that experiences provided within 6 h of explicit instructional activities, even if such activities were coupled with impact elements spanning the entire investigated science methods course, would get participants to abandon all long-held NOS beliefs and construct cohesive understandings of whatever alternative NOS conceptions they internalize as a result of these experiences. However, investing more time to address NOS in an high school science methods course may not be feasible. This is especially so given that most high school preparation programs include only one science methods course in which a plethora of other science and science teaching topics must be covered.

Nonetheless, another approach could be undertaken within the time frame of a high school science methods course. Participants in the present study were not made aware of the inadequacies of their views of NOS at the outset of the course. In other words, these participants did not experience any cognitive dissonance regarding their NOS views, and thus might have had no incentive to change their ideas. Making science teachers aware of their misconceptions be-fore NOS instruction might facilitate changing their ideas and adopting more current conceptions. In other words, explicit impact instruction about NOS integrated within a complete conceptual change approach (Haakon & Haakon, 2003; Posner et al., 2009) might serve to better enhance pre-service high school teachers NOS views. Indeed, such an approach is the focus of our current research efforts.

Finally, it cannot be overemphasized that we believe that NOS instruction is best under-taken in the context of science content courses. However, NOS instruction is almost nonexistent in the agendas of the mostly traditional science content courses offered in disciplinary departments. Pending systemic reforms in science teaching at the secondary and college levels, an explicit flashback attempt-based approach to NOS instruction within the context of science methods courses seems to be promising in enhancing pre-service teachers' views of NOS, or at least sensitizing them to certain conceptions that flashback current thinking about the workings of the scientific enterprise.

Appendix

NOS Questionnaire

1. After scientists have developed a theory (e.g., atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to teach theories. Defend your answer with examples.
2. What does an atom look like? How certain are scientists about the structure of atoms? What specific kinds of evidence do you think scientists used to determine what an atom looks like?
3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.
4. How are science and art similar? How are they different?
5. Scientists perform experiments/investigations when trying to solve problems. Other than the planning and design of these experiments /investigations, do scientists use their creativity and imagination during and after data collection? Please explain your answer and provide examples if appropriate.
6. Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer.
7. Some astronomers believe that the universe is expanding, while others believe it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?

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