Do pre-service science teachers have understanding of the nature of science?: Explicit-reflective approach

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Contents

Abstract

Current approaches in Science Education attempt to enable students to develop an understanding of the nature of science, develop fundamental scientific concepts, and develop the ability to structure, analyze, reason, and communicate effectively. Students pose, solve, and interpret scientific problems, and eventually set goals and regulate their own learning by doing science and reasoning scientifically (NRC, 2000; Rutherford & Ahlgren, 1991). This study investigated pre-service science teachers' views about the nature of science (NOS) and considered an explicit-reflective instructional practice to promote pre-service science teachers' appropriate NOS views. Methodology for this study included: VNOS-C (Abd-El-Khalick, Bell, & Lederman, 1998; Lederman, Schwartz, Abd-El-Khalick, & Bell, 2001), Myths of Science survey (McComas, 1998), associated interviews that tracked the changes in the NOS views of pre-service science teachers at the end of the course, and video-records of the NOS workshop in the second semester. Pre-service science teachers were interviewed by using the VNOS-D (Lederman & Khisfe, 2002) to track changes in their NOS views at the end of the course. Based on the results from the analysis of the surveys, interviews, and video-recordings, pre-service science teachers made substantial increases in their views of the NOS aspects. Less considerable gains were evident in the case of the subjective, social and cultural aspects of the NOS. The results of this study support the impact of an explicit-reflective NOS instruction.

Keywords: explicit-reflective, nature of science, VNOS-C; VNOS-D, myths of science

Introduction

Enhancing students' understanding of the nature of science (NOS) is crucial for achieving scientific literacy and a major and significant goal of all recent reform movements in science education (American Association for the Advancement of Science (AAAS, 1989, 1993); National Research Council (NRC, 1996)). Science teachers' views about the NOS are very important in the present efforts of the Ministry of Education in Bahrain to reform science education as well. Teacher preparation programs in the Middle East before the educational reform mostly focused on teaching scientific knowledge with selected education courses. Pre-service science teachers were not exposed to the epistemology and philosophy of science. On the other hand, only a small part of a methodology course covered the NOS as a topic, but it was taught using a Baconian view (Haidar, 1999) not a constructivist view. According to the Bacanion view, scientists can observe and predict what is happening in the world from an objective perspective. The only way to learn scientific knowledge is through induction. In other words, scientists should be objective and they cannot use their imagination and creativity. Scientific knowledge is not tentative and lacks creativity and imagination (Chalmers, 1999).

In the Middle East, most in-service teachers, pre-service teachers, and students are not familiar with the NOS. They generally have a Baconian perspective that scientific knowledge is obtained by induction from conducting experiments (Kalman, 2010), a relatively naïve view about the NOS. Students and teachers rely heavily on science textbooks that present science as a collection of facts and principles and use cookbook activities that portray the resulting products of science without referring to how the scientific knowledge was developed. Students can see only the products, but not the process. Even some university professors still hold naïve views about the NOS. (BouJaoude, 1996; Pomeroy, 1993).

Research studies have shown that students hold naive views of the NOS despite the fact that the importance of the NOS has been accepted in the science education community and emphasized in the science courses and science method courses (Horner & Rubba, 1979; Larochelle & Desautels, 1991; Mackay, 1971; Rubba, Horner, & Smith, 1981; Akerson & Hanuscin, 2007; Khishfe, 2008; Bell & Lederman, 2003). In addition, studies have shown that pre-service science teachers, as well as in-service science teachers, do not have adequate conceptions of the NOS (Seung, Bryan, & Butler, 2009). One of the reasons is the lack of emphasis or less emphasis on the NOS in the science courses and science method courses in most teacher preparation programs (Matkins, Bell, Irving, & McNall, 2002). To promote students' understanding of the NOS, different curricular and research studies were developed and conducted, however it was found that these attempts were not completely effective in promoting students' understanding of the NOS (Crumb, 1965; Jungwirth, 1970; Meichtry, 1992; Trent, 1965; Welch & Walberg, 1972; Khishfe, 2008). Abd-El-Khalick and Lederman (2000) stated that these attempts were ineffective because it was assumed that students would learn the NOS automatically as a result of studying science by inquiry activities. In other words, students learn best the aspects of the NOS through explicit-reflective instruction as compared to implicitly through experiences simply “doing” science (Lederman, 2007).

In addition, most teacher education programs try to include several NOS lessons in the science teaching method courses like our pre-service science teaching method courses at Bahrain Teachers College in Teaching and Learning General Science 1, Teaching and Learning Biology 1, Teaching and Learning Chemistry 1, or Teaching and Learning Physics 1. That is, most pre-service science teachers receive their primary NOS learning in the science teaching method courses. However, little effort has been made to develop a module that is suitable for teaching the NOS in the science teaching methods courses (Seung et al., 2009).

Based on experience with in-service and pre-service science teachers, it was noticed that most held naive views of the NOS consistent with the Baconian views about science and some resistance to change those beliefs. Research shows that science teachers who hold naive views about science may not be able to implement reform in science education. If the current reform in science education in Bahrain has to succeed, it would be helpful to know science teachers’ beliefs about the nature of science.

In this paper, pre-service science teachers’ views about the nature of science enables us to consider what pre-service science teachers are likely to communicate about the NOS in their professional practice when they become science teachers after their completions of PGDE (Post Graduate Diploma in Education). This provides insights into pre-service teachers’ starting points about their views of the NOS and how they develop and build views about the NOS that are more pedagogically sound. The analysis provides a framework to characterize pre-service science teachers’ views about the NOS in their discourse. The framework is based on the data collection and results of the data, as well as aspects of the NOS. The nature of science (NOS) and its characteristics were defined based on the way scientific knowledge is developed (Lederman, 2007; Abd-El-Khalick, B ell, & Lederman, 1998; Lederman, N,G. et al., 2001; Khishfe, 2008; Seung et. al, 2009) as seen in Figure 1 reported in the literature. The paper is concluded by drawing out some important implications of this research for science teacher education.

Structure of the course

The current PGDE secondary science teacher education programme at Bahrain Teachers College in Bahrain, instituted after the educational reform in 2008, is a one-year full time programme. In-service teachers have already had one year to three years teaching experience, but without pedagogical knowledge background. Most just have a BS degree in sciences like physics, chemistry, and biology, and were then selected to the PGDE programme based on criteria of Ministry of Education in Bahrain. This PGDE programme includes Teaching and Learning General Science 1, which covers the following topics: Nature of Science, planning for science teaching, learning theories, and contemporary teaching approaches. It also includes Teaching and Learning Physics 1 and 2, Teaching and Learning Chemistry 1 and 2, Teaching and Learning Biology 1 and 2. These courses also cover almost all the same topics, but as specifically relates to the subject matter. Based on pre-service science teachers' background, they will be taking some of these courses. For example, if their background is physics, they should take Teaching and Learning Science 1 and Teaching and Learning Physics 1 and 2. The nature of science is covered in week 2(3h) in Teaching and Learning General Science 1 and Teaching and Learning Biology 1. If students' background is physics or chemistry, they will not be exposed to the NOS topic more than once. It discusses three aspects if science: fundamental of science, principles of science, and characteristics of science.

The Teaching and Learning General Science 1 course was used in this study, as it was the only available context in which to investigate the influence of approaches to the NOS teaching. The basic assumption of this preliminary study was that the inclusion of an explicit-reflective approach would contribute to developing pre-service science teachers' understanding of the NOS. It was offered in the first semester (Fall 2008) of the PGDE programme to pre-service science teachers. Along with this course, they took either Teaching and Learning Biology 1 or Teaching and Learning Chemistry 1, based on their background. There were no students whose background was physics.

The interactive/dialogic approach in interactive lecture was used to explore students' knowledge (Chin, 2007). The goal was to encourage students to elaborate on their thinking and assist them to construct conceptual knowledge about the NOS (VanZee & Minstrell, 1997b).The classroom was designed by the instructor of the course with round tables because contemporary teaching approaches require moving from lecture mode to cooperative mode and interactive-engagement approach. During round-table small group discussions, students conducted hands-on and minds-on activities regarding the NOS that could promote science knowledge construction.

Purpose of study and research questions

Current approaches in Science Education are to allow students to develop an understanding of the nature of science, fundamental scientific concepts, and the ability to structure, analyze, reason, and communicate effectively. They should pose, solve, and interpret scientific problems, set goals, regulate their own learning by doing science, and learn to reason scientifically (NRC, 2000; Rutherford & Ahlgren, 1991). This study considered views of the nature of science (NOS) of pre-service science teachers and instructional practice to promote pre-service science teachers' appropriate nature of science views. This study was guided by the following questions:

1. What were pre-service science teachers' views of the NOS?
2. What was the influence of the explicit constructivist-inquiry oriented approach on pre-service science teachers' views of the NOS?
3. How did pre-service science teachers' understanding of the NOS develop from pre- to post- tests?

In general, the NOS is related to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992). In the literature, especially in Science for All Americans (AAAS, 1989), pedagogically important aspects of the NOS are highly developed (See Figure 1). In this study, the focus was on Bahraini pre-service science teachers' understanding of the considered aspects of the NOS.

Methodology

Context of the study

Data were collected in the Fall 2008 semester in which participants were enrolled in the course of Teaching and Learning General Science 1 at Bahrain Teachers College, University of Bahrain, Kingdom of Bahrain. This course was designed as part of the one-year PGDE programme for pre-service science teachers. The course focused on approaches for teaching general science and includes explicit-reflective activities that emphasize constructivist-inquiry-based instruction to help pre-service science teachers improve their and their students' views of the NOS (Akerson & Hanuscin, 2007). In the same semester, pre-service science teachers took Teaching and Learning Biology 1 and Teaching and Learning Chemistry 1.

25 pre-service science teachers (24 female and 1 male) were participated to the study. Six of them (5 female and 1 male) volunteered to participate in interviews. None of the 25 participants had taken any courses or course work related to the NOS before they started PGDE programme. They stated that this course was the first course in their educational life that explicitly taught the concept of the NOS.

A three-hour workshop was also conducted by the author to the same class on the NOS in spring 2009. The workshop was videotaped and their work in the workshop was analyzed in terms of some aspects of the NOS (Figure 1).

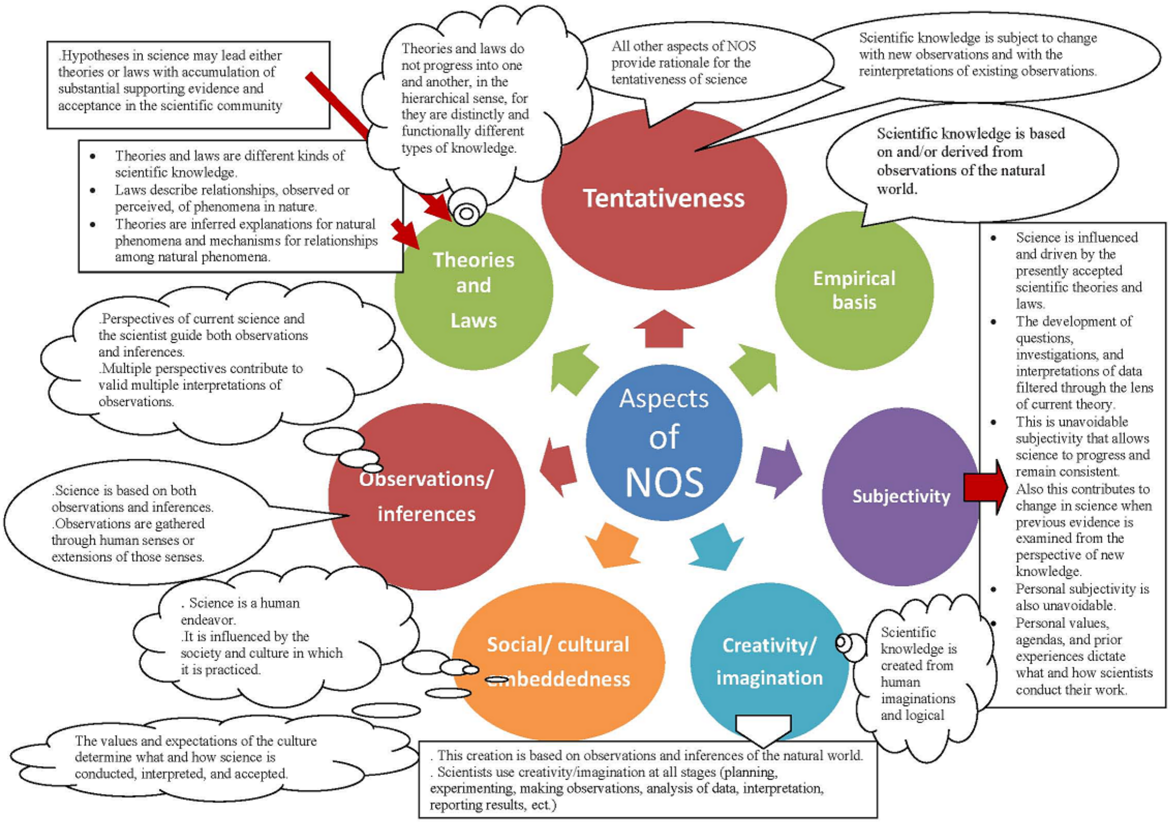


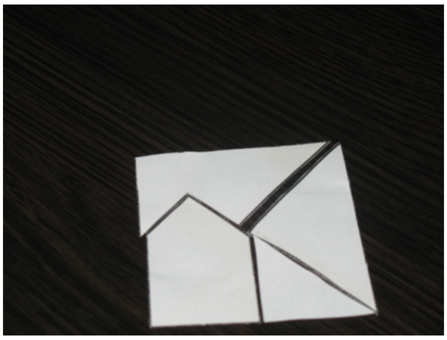
Figure 1. Aspects of the NOS

The instructional approach-intervention

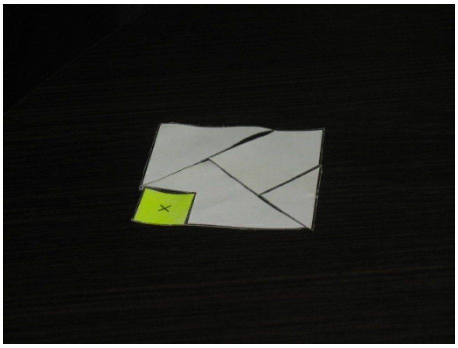
I developed and implemented an explicit-reflective non-context based approach to the NOS teaching for a science method course. Pre-service science teachers were engaged in two activities taken from the literature (Lederman, & Abd-El-Khalick, 1998; McComas, 1998) that were selected according to the instructional approach. The Puzzle Activity and The Trick Tracks Activity were purposely selected to introduce and reinforce to pre-service science teachers' understanding of the main aspects of the NOS. These activities can be found on Internet Web sites and in books as an explicit-reflective instructional approach to the NOS (McComas, 1998; Akerson, Abd-El-Khalick, & Lederman, 2000). In teacher education, reflective approach is the usage of reflections for the personal and professional development of teachers (Rosenthal, 1991). Students can reflect on their understanding and articulate and elaborate their acquired NOS understanding.

The Puzzle Activity (Choi, 2004) is about getting the students to think about the nature of science, and also, showing the importance of being an active participant in the learning process. Students know the definition of science based on the out-dated Baconian view, but they should realize that science is dynamic, it is hands-on and minds-on, and it changes as our knowledge of the world increases.

The procedure for this activity is as follows: Pre-service science teachers are given all the pieces except the small square marked X (Figure 2b). Each piece represents current scientific data. Once the pre-service science teachers are given the pieces, no further instruction should be given; most pre-service science teachers will begin to arrange the pieces on their own. In a short amount of time, the pre-service science teachers will put the pieces together to make a square easily. After the pre-service science teachers have arranged the pieces to produce Figure 2a, the small square marked X is given to each student and explain that a new scientific discovery has been made. The pre-service science teachers must someway incorporate this new information to their puzzle. Students should be encouraged to work individually at first, and then, to work in groups if they are still struggling to put the pieces together. You should not allow them to share their arrangements at this stage. If one gets the correct arrangement, have that student cover up the answer. Group discussion and class discussion are encouraged during the second part of this activity to have their reflections on how they solved the puzzle and what procedures they followed. In addition, you can ask students to reflect on how scientists work and solve the problems that they confront. The pre-service science teachers' work with regard to the puzzle activity is shown in Figure 2 a and b.



(a)



(b)

Figure 2(a), (b). Pre-service science teachers' work on the puzzle activity

The Tricky Tracks activity (Lederman, & Abd-El-Khalick, 1998) was purposely selected to introduce and reinforce the pre-service science teachers' understanding of the main aspects of the NOS. This activity conveys to students the message that there is no a single 'correct' answer. Based on the same set of data (observations), several valid answers to the same question can be obtained. The goal of the activity is to help students distinguish between observation and inference. The procedure for this activity is as follows: 1) students are shown foot print 1 and asked what they observe. Students immediately tell their inferences like "bird tracks or big bird and small bird tracks or necklace" without knowing that their descriptions are inference. 2) Students are shown foot prints 2 and 3 to discuss further observation and inference. This activity is well designed to discuss the difference between observation and inference. It provides an opportunity for students to understand the difference between observation and inference and reflect on the way in which scientists work. It illustrates how scientists might reach several valid answers to the same question based on the same set of observations or data.

Workshop

A workshop was conducted in the second semester for three hours to enhance the pre-service science teachers' understanding of the aspects of the NOS through explicit-reflective instruction. Examples of several hands-on and minds-on activities taken from the literature follows (all activities were used to find out the pre-service science teachers' views on certain aspects of the NOS and to reinforce their understandings of the NOS aspects):

1. The cube activities (Lederman, & Abd-El-Khalick, 1998) (imagination, creativity, human inference): This activity focuses on scientific knowledge being based on human inference, imagination, and creativity. Scientists often look at the data they collect for certain patterns or regularities, as illustrated in this activity (it has certain patterns and regularities). Scientists then extrapolate their data in order to provide predictions for future behavior of the physical phenomena that they have been investigating based on the patterns and regularities.

The procedure for this activity is that students are divided into small groups and given several cubes that have different patterns. They can see all the sides of the cube except the bottom side. They are asked to find out what is on the bottom side of the cube. For example, on one cube consecutive consonant letters of English alphabet make meaningful words, so one group of the pre-service science teachers' work on finding out the word on the bottom of the cube; please see Figure 3 and 4, respectively. BAT and CAT, FAT and HAT, and MAT and PAT.

Figure 3. Pre-service science teachers' work on the cube activity

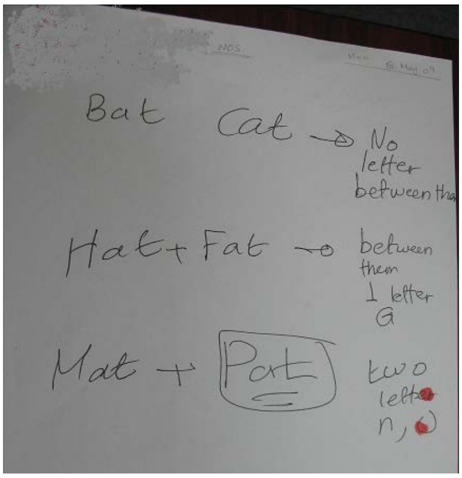


Figure 4. Pre-service science teachers' work on the cube activity

2. Young? Old? Activity (Lederman, & Abd-El-Khalick, 1998) (science as theory-laden and subjective, socially and culturally embedded): This activity focuses on constructing scientific knowledge which can be influenced by scientists' previous knowledge, training, and experiences.

The method for this activity is that students are divided into small groups and shown several different pictures with portraits of both an old lady and a young lady portraits embedded in each picture.

Pre-service science teachers are asked to tell what they see in each picture.

3. Elephant's Legs (science as theory-laden and subjective, socially and culturally embedded): This activity focuses on constructing scientific knowledge that is affected by scientists' previous knowledge, training, and experiences as well. The method for this activity is the same as described in the "Young? Old? Activity". A Lipton tea bag label (Figure 5) was used in this activity. Students were amused to realize that they could find different materials from their daily life to teach some aspects of the NOS.

Figure 5.

4. The Puzzle activity (tentative scientific knowledge): This activity stresses that scientific knowledge is subject to change with new observations and with the reinterpretations of existing observations. The method for this activity is same as in previous sections.

A small group and then a whole-class discussion was conducted for each activity that aimed to explicitly highlight the aspects of the NOS and involve students in active discourse regarding their ideas on some aspects of the NOS. In these discussions, I encouraged students to make links between the activities applied and scientists' real life experiences toward developing scientific knowledge.

Subsequent discussions focused on the distinction between observations and inferences, the tentative nature of scientific knowledge, theoretical constructs in science, the role of creativity, imagination, and background knowledge, and the impact of the social and cultural factors in devising scientific explanations. This non-context based NOS instruction was intended to provide the pre-service science teachers with a NOS framework by introducing and sensitizing them to these aspects of the NOS.

Theoretical framework for the study: Phenomenography

Since this study was concerned with pre-service science teachers' views and understanding of the NOS, the design of this qualitative study was viewed within a phenomenographic framework.

Phenomenography is the study of the different ways in which people experience the world. In other words, its aim is to discover the range of ways people in a group experience, conceptualize, notice, and understand various aspects of phenomena in the world around them (Bowden et al., 1992). In phenomenographic research, the researcher chooses to study how people experience a given phenomenon (Ornek, 2008). A phenomenographic framework was used to ascertain how the pre-service science teachers understand the aspects of the NOS.

Data collection

Data were collected from multiple sources:

- Using the VNOS-C, the Views of Nature of Science version C (Abd-El-Khalick, Bell, & Lederman, 1998; Lederman, Schwartz, Abd-El-Khalick, & Bell, 2001).
- The Myths of Science survey (McComas, 1998) explores widely-held, yet incorrect ideas about the aspects of the nature of science.
- Associated semi-structured interviews: to track the changes in the NOS views of pre-service science teachers by using the VNOS-D, The Views of Nature of Science version D (Lederman & Khisfe, 2002) at the end of the course.
- A workshop was conducted about the NOS in the Spring 2009 to follow up pre-service science teachers' progress vis-à-vis understanding of the aspects of the NOS and video-recorded.

The questionnaires, the VNOS-C, and the Myths of Science were all designed to elucidate participants' views regarding the components of the NOS and underlying their views. In addition, the VNOS-D survey was used for semi-structured interviews to elucidate pre-service science teachers' own views with regard to aspects of the NOS. Open-ended survey items including interview questions allow the pre-service science teachers to reveal their own opinions regarding the aspects of the NOS and the reasons that underlie their views (Lederman, 1992; Lederman & O'malley, 1990). The ten-item open-ended survey (VNOS-C), the 15-item open-ended survey(Myth of Science), and the seven-item open-ended survey (VNOS-D) used in this study were previously applied and validated by Abd-El-Khalick (1998) and Lederman et al. (2001), McComas (1998), and (Lederman & Khisfe, 2002).

The main research question that guided this study were "What were pre-service science teachers' views of the NOS? and What was the influence of the explicit constructivist-inquiry oriented approach on pre-service science teachers' views of the NOS?". Qualitative design was used to answer the research questions. The study data were collected in Fall 2008 and Spring 2009, using an open-ended survey, The Views of the Nature of Science Form C (VNOS-C) was used to assess participants' views of the NOS before and after the Science Method course, Teaching and Learning Science 1. This survey consists of ten open-ended items that assessed participants' views of the tentative, creative, empirical, and subjective nature of science; social and cultural embeddedness in science; observation and inferences; and theories and laws. In addition to the VNOS-C, the Myth of Science Survey was used to investigate participants' views of the NOS prior to and at the end of the course. This survey consists of 15 open-ended items that probe participants' views of the same issues as the VNOS-C does. The author implemented the teaching activities, and then conducted semi-structured interviews with all pre-service science teachers at the end of the course using the VNOS-D survey. This survey consists of the seven open-ended items that investigates participants' views of the NOS with regard to the aforementioned aspects of the NOS. Interviews aimed to investigate participants' views of the NOS in depth. Interview findings were also used to examine the validity of pre-service science teachers' post-test responses to the survey items because what they had written might not have reflected what they explained in the interviews.

Data analysis

During the Fall 2008 semester, pre-service science teachers' understanding of the NOS was examined through the use of the VNOS-C and the Myths of Science survey. 25 pre-service science teachers completed the surveys as a pre-test and post-test. After the first semester, 6 of them took part in semi-structured interviews in which the VNOS-D was used to elicit more detailed responses in relation to pre-service science teachers' responses on the questionnaires. All interviews were audio-taped and transcribed for analysis.

Two types of triangulation were used to establish credibility of the results of survey, interview, and video records data. One was to involve another investigator's interpretation of the data obtained from both surveys and independent interviews (Patton, 2002). We compared the findings and found that our results were compatible. This approach was carried out because the researcher was also the instructor of the course. Otherwise, it would not be possible to avoid the researcher's bias. The second method of triangulation was to include the primary data in the results. The inclusion of excerpts from the interviews allows the reader to see exactly the basis upon which the conclusions were made.

Data obtained from the surveys, corresponding interview transcripts of all pre-service science teachers, and transcripts of the video records, were all analyzed using inductive analysis with the assistance of a data-management software program called ATLAS-Ti. Major coding categories derived from the data were formed to make sense of pre-service science teachers' responses and to describe the variety of their responses. I created the coding categories for an initial coding scheme for data from surveys, interviews, and video records. After that, the other researcher was involved in coding to establish consistency of the analysis. Another researcher and I computed the reliability of the data by comparing coding decisions using the inter-coder reliability formula: Reliability= [number of agreements / (total number of agreements + disagreements)] (Miles & Huberman, 1994, p.64).

According to the results of the calculations, the inter-coder reliability levels for pre-and post-tests, interviews, and video analysis were 0.75, 0.84, 0.92, and 0.90 respectively. We reexamined the contradictory evidence in the data and decided to do some further refinement of coding categories. As a result, we found our results were compatible after some modification of coding categories.

The categories were tentativeness; empirical basis; subjectivity; creativity/imagination; social/cultural embeddedness; observations/inferences;

theories/laws. The same procedure was done by the other researcher to confirm reliability in the data and we found our results were compatible. Moreover, the data obtained from the NOS surveys were generated into pre-instruction and post-instruction profiles of pre-service science teachers' views of the NOS in the course. Some quotes were used to support the assertions made and enrich discussions.

Results

This part elucidates pre-service science teachers' views of the NOS in pre-instruction and post-instruction focusing on the aforementioned aspects of the NOS. It also reveals their views about the NOS from the post-interviews conducted at the end of the course and during the NOS workshop conducted in the Spring 2009. The transcripts and quotations from the pre-test and post-test, interviews, and video records contain the following shorthand notation: [ ] represents comments about the interview added after the fact, {…} indicates that unimportant words were omitted from the transcript, and inaudible words or sentences were not included. Pseudonyms were used to protect privacy.

Pre-service Science Teachers' Views of the NOS

Pre–Instruction and Post-Instruction

The results of the data analysis from the surveys indicated that there were pre-to post-test differences in pre-service science teachers' views of the NOS. However, they still held naïve views about some aspects of the NOS. At the beginning of the course, pre-service science teachers held many misconceptions regarding aspects of the NOS, according to the results of the VNOS-C and the Myths of Science survey. None of them held expert views of all aspects about the NOS in the pre-instruction even though a few had expert views on the certain aspects. Table 1 presents a summary of the results from the VNOS-C and the Myth of Science surveys administered as a pre-and post-test. Table 2 shows the numbers and percentages of pre-service science teachers who held naïve and expert views of the NOS with regard to the aspects of the NOS before the instruction and after the instruction. As seen Table 1 and 2, the majority of pre-service science teachers held naïve views of the seven aspects of the NOS. None of the pre-service science teachers held expert views of all seven aspects of the NOS at the beginning of the study, which was expected (Akerson, Abd-El-Khalic, & Lederman, 2000) because none of the pre-service science teachers had a course related to the philosophy of science or the nature of science. Therefore, none of them were given opportunities to conceive of science as a human endeavor.

Table 1 and Table 2 show that there was a substantial increase in pre-service science teachers who held expert views of the aspects of the NOS at the end of study. There were significant changes in each aspect of the NOS. Nevertheless, the changes were not complete. They still demonstrated naïve views about some aspects of the NOS even after the course. However, one aspect of the NOS that all pre-service science teachers mastered was the tentativeness of science. In Table 1, the quotes presented in column 2 (pre-test) illustrate views that were considered naïve. Quotes illustrating more expert views were presented in column 3 (post-test).

Table 1. Pre-service science teachers' views of NOS from pre- and post-tests

Aspects of NOS	Pre-test	Post-test
Tentativeness	**Naïve-**science is not tentative ***"Scientific knowledge cannot change because it is absolute."***	**Development** ***"Yes, scientific theory can change if new observation or evidence is found. For example, atom theory has changed many times depend on scientists' imagination and evidences…"*** ***"Scientific theory might change by time because it put by human opinions which may be true or wrong, for example biologists first proposed that the genetic material is composed of proteins. Then, this was changed and moved to be nucleic acids (genetic material is composed of nucleic acids)."***
Empirical basis	**Mostly Naïve-** science is based on experiments. "***Development of scientific knowledge requires experiments, because experiments will test and prove the facts and show the true roles that will guide to more understanding and more true facts of science."*** ***"…because the knowledge in science is gained through research and that research doing by experiment and the experiment is important and essential and the main structure of scientific knowledge as a***	**Still Naïve-** but development in TCs' views of this aspects. ***"It [science] is a human endeavor that to explain how the world works."*** ***"[Science] is the effort to discover, and increase human understanding of how the physical world works. Through controlled methods, scientists use observable physical evidence of natural phenomena to collect data, and analyze this information to explain what and how things work."***

	backbone…"	
Subjectivity (theory-ladennes)	**Mostly Naïve-** science is universal. ***"Science is universal and does not depend on the social and cultural values because science is the same in every where does not affected…"***	**Still Naïve-** but development in TCs' views of this aspects. ***"…because they [scientists] have different ways of thinking and analysis of the data."*** ***"Because every scientist look at data from different side and think differently and each group deal and use this data in different way or procedure…"***
Creativity/imagination	**Mostly Naïve-** scientists do not use creativity/imagination at all stages of investigation. ***"I think scientists use their creativity and imagination during their investigations. The use of imagination and creativity in planning and designing to help them in their work. The imagination and creativity can be used during or after collecting the data but in low levels."*** ***"Yes, I believe that they [scientist] use their imagination. That is satisfied by theories. Theories are type of imagination that are used to explain observations and these theories [imagination] can be changed by time. I think scientists use their imaginations after data collection stage to try explain these data and why they come in this way… Scientific method is a universal that because it could be applied anywhere. It is independent on culture and social values."***	**Still Naïve-** but development in TCs' views of this aspects. ***"Yes, in planning and design, to help provide meaning to experience and understanding the knowledge, and to help to collect the data ad develop the method…"[She believed that scientists use their creativity/imagination only at planning and designing stages.]*** ***"Scientists use their creativity in almost all stages. To design experiments in order to collect data, and then formulate these data into meaningful hypothesis."***
Social/cultural embeddedness	**Mostly Naïve-** science is universal. ***"Science is universal. It doesn't reflect social or cultural values. That is because science contacts with the nature and events in it. It doesn't have any relation with social or culture to affect it…"*** ***"I agree that science is infused with social and cultural values because science is related to cultural, and social and philosophical assumption, we are Muslim and the knowledge required in Islam but we must take in mind the legitimacy term for***	**Still Naïve-** but development in TCs' views of this aspects. ***"Scientist isn't universal and a part of my religion [Islam]. Each civilization on earth has taken its own route in the pursuit of knowledge and interaction between those civilizations... Therefore there are no universal science on this planet."*** ***"Science should be universal but some time it affected by the culture for example non-Islamic world can use science to make cloning but***

	example genetic science is important in science but we cannot use all application like cloning in human or animals because it is interference of God's creation."	***it's not acceptable with Islamic world."***
Observations and inferences	**Naïve-** ***"…scientists constructed the model depending onobservations [inferences] and from experimental conclusions and by recording effects and properties about atoms. [Pre-test-atomic structure]."***	**Still Naïve-** but development in TCs' views of this aspects. ***"atom it's not some thing that you can see, they reach to this structure through imagination, creativity [inference] and through measuring electricity…"*** ***"Scientists simulate structures [inference] (e.g. the atom) according to what they got/found from their experiments (e.g.radiations). Scientists may be not 100% sure about the accuracy of models, but they design them based on data/results/effects to simplify their investigations."***
Theories and laws	**All Naïve-**hypothesis—theory—law ***"…hypothesis become theories which become laws."***	**Still Naïve-** but development in TCs' views of this aspects. ***"Theories and law are very different kinds of knowledge one simply does not become the other."*** ***"This is the typical sequence but not always necessary. We might have a law without having a theory."***

Table 2. Pre-service science teachers' views of NOS in percentages from pre- and post-tests

	Pre-instruction		Post-instruction	
NOS Aspects	**Naïve (N/%)**	**Expert (N/%)**	**Naïve (N/%)**	**Expert (N/%)**
Tentativeness	**25/100**	0/0	0/0	**25/100**
Empirical basis	22/88	3/12	6/24	19/76
Subjectivity (theory-ladenness)	23/92	2/8	4/16	21/84
Creativity/imagination	24/96	1/4	10/40	15/60
Social/cultural embeddenness	23/92	2/8	2/8	23/92
Observations vs inferences	**25/100**	0/0	6/24	**19/76**
Theories and laws	**25/100**	0/0	5/20	**20/80**

Note: The aim was not to use quantitative analysis, but showing in numbers can provide another way of looking into the data.

Interviews

Table 3 illustrates the results of the interviews with the six pre-service science teachers after the instruction. Profiles of pre-service science teachers generated from the data analysis of these interviews revealed the influence of the workshop on their conceptions of the NOS (Table 3). Only two of them held more expert views of aspects of the NOS. Five of them still held naïve views regarding some aspects of the NOS. For example, three of them exhibited naïve views on the empirical basis of the NOS. They stated that science is based on experiment and conducting experiments is required to assure the results.

Ahmed held several views consistent with the targeted aspects of the NOS after instruction. However, he still held a few naïve views regarding the targeted aspects of the NOS. He viewed that science needs evidence and experiments to validate the results stating that "science depends on evidence and experiment and science needs evidence and experiments to ensure the results". He also acknowledged scientific knowledge as constructed, rather than discovered. In addition, he was able to link his understanding of the important role of observation and inference in science as being subjective because subjectivity related to scientists' backgrounds influence how they interpret data. He held complete understanding of the tentativeness of scientific knowledge. As a result of the explicit-reflective NOS instruction, he improved his views on most of the targeted aspects of the NOS, except for the empirical basis of the NOS. He believed that science was different from other subjects because scientists relied exclusively on empirical evidence. On the other hand, he had a conflicting view with respect to observation and inference because he stated that scientists made inferences from data such as bones, DNA, and footprints. Regarding the socio cultural effect of the NOS, he stated that religion influences science.

Aisha demonstrated very good explanations of the targeted aspects of the NOS after the instruction. She acknowledged that scientists have their own explanations for the data they obtained. She was successful in understanding the distinction between observation and inference using the explanation of the dinosaur question. She also indicated that scientists use their imagination and creativity, giving an example that they have to figure out how to put bones of dinosaurs together, then color and shape of them. Her explanation regarding theory was very informative: She pointed out that scientists' prior experiences and background affect the interpretation of the data. She also explained that religion influences on science because Muslim scientists, for example, interpret the data by considering rules of Islam, so they cannot be objective.

Fatima also had very convincing explanations of the targeted aspects of the NOS. She demonstrated understanding of the aspects of the NOS.

Mariam held naïve views regarding the empirical basis of the NOS as she stated that science was based exclusively on evidence and experiment even though she later indicated that observation and inferences are parts of science. So her views contradicted this aspect of the NOS (observation/inference). On the other hand, she held good explanations regarding other aspects of the NOS, especially concerning theories and laws. She acknowledged that they do not progress in a hierarchical order. It was substantial change because she had thought that hypothesis leads to theories and then to laws. In addition, she held consistent views with other aspects of the NOS (e.g. science involves creativity and imagination in all stages, scientific knowledge is subjective, and religion affects science).

Zahra held mostly naïve views on most aspects of the NOS with conflicting ideas of some aspects of the NOS. For example, she stated that science is objective not subjective; nevertheless, she also mentioned that science depends on scientists' perspectives. Another example is that she stated that science is tentative, but also that scientific models are fixed. All statements demonstrated that she did not improve her views and had conflicted ideas about some aspects of the NOS.

Afaf held a few naïve views of the aspects of the NOS and did not demonstrate any conflicted ideas of the aspects of the NOS. She articulated clear descriptions of most of the aspects of the NOS. She stated that scientific knowledge changes indicating an expert view of the tentative nature of science. She also articulated theory-ladenness of the NOS indicating that science was influenced by scientists' background and perspectives. She was aware of observations and inferences were part of science and explained by using dinosaurs' example saying that scientists made inferences from their observations such as their bones, DNA, and footprints. On the other hand, she stated that imagination and creativity were not included at all stages of investigations especially indicating reporting results whereas these two are used in planning, experimenting, making observations for inferences, analysis of data, interpretation, and reporting results. She seemed to still believe that reporting results should be more objective. Other than this naïve view, she described other aspects of the NOS well and used examples in the interview questions, such as dinosaurs and weather examples.

Table 3. Pre-service science teachers' views of NOS from interviews

Teacher	Views from interview (after the course)
Ahmed	• Science is a body of knowledge. • Science depends on evidence and experiment. • Science is different from other subjects. • Science needs evidence and experiments to ensure your results. • Scientific knowledge changes. • Science involves imagination. • Religion affects science. • Scientific model is not fixed. • Science is based on both observation and inference *(He explained that they [scientists] collected the bone, from the bones of dinosaurs* ***[observation]*** *they found some remains of dinosaurs of bone that collected and joined them…then they imagine the skin and they make it (inference).* • There is no absolute truth. • Theories and laws do not progress into one and another, in the hierarchical sense
Aise	• Science is a description of studying how the world works and how the everything in the world operates. • Scientific knowledge changes. • Science is tentative. • Science involves imagination. • Scientists' prior experiences and ideas dictate what and how scientists conduct their work. • Religion and culture influences science. • Imagination/creativity is used at all stages of investigations. • Science involves observation and inferences *(…they [scientists] are very accurate in their observations but they see things from different perspectives [inferences]).* • Theories and laws do not progress into one and another, in the hierarchical sense
Fatima	• Science is studying what happens around us, everything in the nature. • Science is tentative (science is always changing). • Science involves observations and inferences. • Scientific knowledge is not absolute truth. • Bias is inherent in the development of scientific knowledge (scientists' prior knowledge and experiences). • Scientific model is not fixed. • Creativity and imagination are a part of science. • Imagination/creativity is used at all stages of investigations *(during, planning, experimenting, making observations, and interpretation of data scientists should use their imagination/creativity).* • Theories and laws do not progress into one and another, in the hierarchical sense
Mariam	• Science is based on evidence/experiment. • Science is solving a problem around us. • Scientific knowledge can change in the future *(she gave atomic theory, how it has been changed so far).* • Observing and inference are parts of science *(shape of dinosaurs)*. • Scientists' ideas are influenced by their prior knowledge and experiences. • Religion can affect science (whether prediction). • Scientists use their imagination/creativity at all stages of investigations except including results. • Theories and laws do not progress into one and another, in the hierarchical sense, for they are distinctly and functionally different types of knowledge.

Zahra	• Science is objective more than subjective. • Science is the knowledge that depends on what happened our nature like biology science, chemistry, physics science. • Science is reality. • Science changes (science is tentative). • Observations/inferences are part of science (dinosaurs). • Science is not influenced by religion. • Science depends on scientists' perspectives. • Models are fixed. • Imagination/creativity takes place at all stages of investigations. • Theories and laws do not progress into one and another, in the hierarchical sense
Afaf	• Science is based on observations. • Science is about knowledge. • Scientific knowledge change continuously. • Science is influenced by scientists' background and perspectives. • Observations and inference take place in science (dinosaurs). • Imagination/creativity is a part of science (dinosaurs). • Science may not provide absolute truth (weather). • Imagination/creativity is not used at all stages of investigations. • Theories and laws do not progress into one and another, in the hierarchical sense

Workshop

As indicated before, a workshop was conducted in the spring 2009 semester for 3 hours using several hands-on and minds-on activities, such as cube activities. Comprehensive focus was on the aspects of the NOS that were covered in the workshop. Pre-service science teachers had opportunities to reflect and discuss with their groups and the whole class with regard to aspects of the NOS, except theories and laws because it seemed that pre-service science teachers did not have naïve views regarding that aspect of the NOS. I decided to focus on the tentativeness, empirical basis, subjectivity, creativity/imagination, social/cultural embeddedness, and observations/inferences aspects of the NOS.

After the real life activities, were conducted by pre-service science teachers, class discussions took place and they were asked to write their views with regard to the considered aspects of the NOS on the flip chart as seen Figure 6 (a) and (b). Even if they had naïve views regarding some aspects of the NOS, their classmates corrected them such as writing "not flexible (science is not flexible)" then later they changed it and wrote "changeable (science changes)". Based on analysis of the video record, it was found that some of them still held naïve views of some aspects of the NOS such as tentativeness. It was a very promising result that they stated that science is not objective indicating science is influenced by scientists' background, views, and their previous experience. In other words, science is inherently biased towards ideas and theories.

They indicated that science is reliable, but tentative which is an expert view of the NOS aspect of tentativeness. They articulated well other aspects of the NOS such as empirical basis saying that science is based on observations and evidence (can be physical or descriptions), but still they thought that experiments were required too. It seemed that they still thought that experiments were the crucial part of science. Regarding subjectivity, they claimed that science was not objective and biased by scientist's previous experience, knowledge, background, and views (theory-ladenness). They stated that creativity/imagination, and observations/inferences were parts of science too.

On the other hand, it is interesting to see that some of them still thought that science was composed of only Physics, Chemistry, and Biology as seen Figure 6 (b). Others still held naïve views about the definition of science.

Figure 6. Pre-service science teachers' understanding of NOS

Discussions and Implications

In agreement with research done on pre-service and in-service science teachers' views of the aspects of the NOS (Lederman, 1992; Abd-El-Khalick & BouJaoude, 1997; Akerson, Abd-El-Khalick, & Lederman, 2000; Haidar, 2001; Seung, Bryan, & Butler, 2009), pre-service science teachers held naïve views of most of the aspects of the NOS at the beginning of the study.

The criteria for the grouping of naïve and expert views were based on previous studies on the NOS.

The results of this study demonstrate that the explicit-reflective instructional approach to teach the NOS carried out within the context of the science method course, Teaching and Learning General Science 1 was effective in enhancing pre-service science teachers' views of the NOS. Pre-service science teachers seemed to make considerable gains in their understanding of the aspects of the NOS, which is consistent with the studies of Khishfe, 2009; Seung et.al, 2009; Akerson et .al, 2000. It was found that the development of the NOS views when stimulated by the explicit NOS instruction. According to the results of surveys, the interviews, and the workshop, their gains were not consistent across all NOS aspects: They made moderately greater increases in their understanding of the tentativeness of the NOS, the distinction between observation and inference, and the relationship between theories and laws. They demonstrated less substantial gains in the case of subjectivity (theory-ladenness), creativity and imagination aspect of the NOS, and the empirical basis of the NOS.

Consistent with the constructivist view, the discrepant gains in pre-service science teachers' understanding of the aspects of the NOS could be due to the interaction between their pre-instruction and post-instruction NOS views. On the other hand, their differential gains in the preferred understandings of the aspects of the NOS were not equally accessible. Several quotes of pre-service science teachers' views of the subjectivity (theory-ladenness), creativity and imagination aspect of the NOS, and empirical basis of the NOS after the instruction illustrate this point.

Finally, it cannot be stressed enough that the NOS instruction is not taught in the context of science content courses. Moreover, the NOS instruction is not offered in the traditional science content courses in the departments of the Colleges of Science. With educational reform in most countries, an explicit-reflective instructional approach to teaching the NOS within the context of science content and methodology courses will hopefully promote pre-service science teachers' understanding of the NOS and start to sensitize them to the workings of scientific endeavors.

In spite of the favorable changes in pre-service science teachers' views at the end of the study, some of them still held naïve views about one or more of the aspects of the NOS. The biology majors took Teaching and Learning Biology 1 in the same semester and the NOS was also talked in this class. Therefore, it might have some favorable effects on the pre-service science teachers' views. Furthermore, it seemed that more than a half of the participants developed inconsistencies in understanding of the desired aspects of the NOS. Consistent with research on misconceptions or alternative conceptions (Abd-El-Khalick & Lederman, 2000; Matson & Aprsons, 2006), participants showed the persistence on misconceptions with regard to some aspects of the NOS. It may be because they developed these naïve views of the NOS over years of Bacanion influenced instruction.

The present study has implications not only for the continuing development of the NOS teaching modules, but also for science teacher educators and instructors in college of sciences who wish to design modules for the NOS or to include it in their science courses. For instance, a physics professor can include a topic on the NOS in his/her curriculum before starting the physics topics so that students can be aware of the aspects of the NOS. Otherwise, most of the students will be puzzled when they are eventually exposed to the NOS.

This study represents an initial step in the exploration of pre-service science teachers' NOS views in Bahrain. The NOS instruction needs to be integrated within different context/contents to address the inconsistency in pre-service science teachers' views of the NOS. Finally, three hours for the explicit NOS instruction in a workshop is not enough for pre-service science teachers to abandon their naïve views of the NOS and develop their views of the NOS completely. A separate NOS instruction module should be offered in PGDE programme to develop pre-service science teachers' understanding of aspects of the NOS not embedded into science methodology courses. To enhance students' understanding of the aspects of the NOS, the module should include at least three types of activities. First, explicit, non-context-based activities, such as the cube activity and the tricky track activity should be included. Second, explicit, context-based activities such as Newton's paradigm and Einstein's paradigm should be included too. In this case the situations that are applicable in Newtonian paradigm will not be legitimate in Einstein's paradigm, so students will understand that scientific knowledge is not fixed and correct for all phenomena. Finally, it should discuss the history of science, such as atomic theory. Students can then recognize that a scientific theory changes over time as the atomic theory has changed over time from the ancient Greek Model of Democristus (400BC), to the Dalton Model (1803), Thomson Model (1897), Rudherford Model (1911), Bohr Model (1922), and Wave Model (modern). These components of the NOS course module can improve students' understanding about the tentativeness, empirical basis, development, and the social/cultural influences on scientific knowledge, as well as the function of observations and inferences on constructing scientific knowledge, and the relationship between theories and laws can be enhanced.

A future study might investigate the efficacy of each specific approach (explicit, non-context-based, explicit context-based, and history of science) to the development of pre-service science teachers' knowledge of the NOS. In addition, it would be valuable to conducti a further investigation on how these science teachers actually employ their knowledge of the NOS as they teach science in schools. Moreover, the results can be analyzed by using a 3 categories scheme-naïve, transition, and informed so that the pre-service science teachers' transition views can be investigated.

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