Science Education International
Vol. 27, Issue 4, 2015, 463-487

How Contextualized Learning Settings Enhance Meaningful Nature of Science Understanding

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ABSTRACT: Exploring different contexts to facilitate in-depth nature of science (NOS) views were seen as critical for better professional development of pre-service science teachers, which ultimately would assure better students' NOS understanding and achieve an ultimate goal of current science education reforms. This study aimed to reduce the lack of information related to the contribution of contextualized settings to gain a deeper NOS understanding by pre-service science teachers and provided evidence to inform researchers for effective teacher education programs. The present study focused on helping pre-service teachers develop their NOS views within a combination of different contextualized settings, coupled with explicit reflective NOS instruction. The study was undertaken with seven pre-service elementary science teachers. Data was collected by administration of open-ended questionnaire. The findings revealed substantial improvements in pre-service science teachers' NOS understanding. The results showed that contextualized learning settings might provide teachers with meaningful deeper understanding of NOS rather than rote memorization of NOS tenets.

KEY WORDS: nature of science understanding, teacher education, contextualized nature of science instruction

INTRODUCTION

The need for enhancing a scientifically literate society is regarded as a vital goal in many countries (e.g. Turkey, USA, UK, Taiwan, China, Germany). Enhanced scientific literacy has been achieved through promoting citizens who understand key concepts of science, be able to think in a scientific way, aware of the interdisciplinary nature of science and appreciate science as a human enterprise, which implies strengths and weaknesses of science. Additionally, a scientifically literate person is expected to be able to use scientific knowledge as a way of thinking related to personal and social

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issues (AAAS, 2001). Correspondingly, achieving scientifically literate citizens requires an improvement of the public understanding of science (Driver, Leach, Millar, & Scott (1996). These authors (ibid, p.12) suggest that public understanding of science involves three stages. The first stage is related to understanding of science content. The second stage is related to an understanding of the scientific approach to enquiry. It involves the ability to define scientific study, distinguishing science from non- science. Moreover, this aspect of science understanding recognizes the role of theoretical and conceptual ideas in framing any empirical enquiry and interpreting the outcomes as well as the understanding of empirical enquiry procedures. The last stage refers to understanding of science as a social enterprise. It refers to understanding of science in society and society in science. It is related with knowledge about science rather than the natural world. It involves understanding of the social organization of science, its mechanism for checking, receiving, and validating knowledge and it also includes recognizing the influence of society and values on scientists' choices and interpretations. These last two stages of public understanding of science are closely related to an appropriate understanding of the nature of science. Accordingly, an appropriate understanding of nature of science has been defined as recognition of purpose of science as seeking for explanations in the natural world, identifying the role of science as social institutions and appreciation of interaction between science and culture, as well as understanding the nature and status of scientific knowledge (Driver, Leach, Millar, & Scott, 1996; Lederman & Abd-El-Khalick, 2000; McComas, 1998. This enables citizens to conceptualize science as a social enterprise and differentiate science from non-science. Additionally, appropriate understanding of how science works have been closely related to students' attitudes towards science and their understanding of science content (Clough & Olson, 2012).

Therefore, appropriate understanding of NOS has been proposed as a crucial component of scientific literacy, which has been also emphasized in numerous science education reforms documents (AAAS, 2001; National Research Council, 2000; MEB, 2013).

Even though an understanding of the nature of science has been claimed to be an important learning outcome for science education for a long time, research studies have consistently shown that both students (Abd-El Khalick & Lederman, 2000; Akerson, Nargung-Johsi, Weiland, Pongsanon, & Avsar, 2013; Lederman, Lederman, & Antink, 2013) and teachers have naïve ideas on the nature of scientific knowledge (Abd-El-Khalick, 2005; Cil & Cepni, 2012; Akerson & Donnely, 2010; Ozgelen, Tuzun, & Hanuscin, 2012; Tanel, 2013). Despite huge attempts to improve both pre- and in-service science teachers' NOS views, recent studies still report science teachers having naïve NOS understanding (Shim, Young, & Paolucci, 2010; Bell, Matkins, & Gansneder, 2011). These naïve views of both students and teachers are more likely to be result of experiences from their science education, which stress only a body of knowledge as constituting science, but overlook how scientific knowledge develops (Bell, 2004). Considering the major role of teachers in shaping students' views of science, science teachers' naïve understanding of NOS has been a crucial factor from keeping them emphasizing NOS explicitly and reflectively (Akerson, Buzelli, & Donnely, 2008; Abd-El-Khalick & Akerson, 2004; Dogan, Cakiroglu, Bilican,& Cavus,2013). It is obvious that both pre-and in-service science cannot teach information that they do not possess. Bearing in mind most teachers hold positivistic views of science, developing more desired views of NOS for science teachers has been a first step to ensure instructional practices comply with contemporary view of science in classes. Therefore, science teacher education programs need to provide opportunities for pre-service science teachers to develop in-depth understanding of NOS views.

A recent review of empirical studies on improving pre-service science teachers' understanding of NOS concluded that an explicit reflective approach was generally more effective in enhancing appropriate conceptions on NOS (Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002; Abd-El-Khalick, 2005). Most studies aiming to improve pre-service science teachers' NOS views were undertaken through decontextualized explicit reflective NOS intervention. Although decontextualized explicit reflective NOS instruction provided learners with opportunities to revise their NOS views without struggling with science content, it was not by itself sufficient to help develop deeper NOS understanding (Buaraphan, 2011; Bell, Matkins, & Gansneder, 2011; Clough, 2006). Neither pre-service teachers nor in-service science teachers without some sort of understanding of NOS could be expected to facilitate students' understanding of NOS. Thus, there was an urgent need to design instructional settings that foster in-depth understanding of NOS views. As a response to calls to explore settings which facilitate in-depth NOS understanding, there have been research providing evidence for the effectiveness of contextualized settings (e.g. history of science, inquiry based) to improve profound NOS views. Moreover, it was also claimed that teaching NOS within a contextualized setting would not only foster in-depth NOS understanding, but also helped teachers translate their NOS views into better teaching (Akerson, Khalick, & Lederman, 2000). Therefore, exploring different contexts to facilitate in-depth NOS views were critical for better professional development of pre-service science teachers, which ultimately would assure better students' NOS understanding and lead to achieving an ultimate goal of current science education reforms. Yet, it was still unknown how the combining of different contextualized settings coupled with explicit-reflective NOS would work for pre-service science teachers' NOS views. Many questions still remained pertaining to explicit reflective instruction within different contexts.

This study aimed to reduce the lack of information related to contribution of contextualized settings to gain deeper NOS understanding for pre-service science teachers and provided evidence to inform researchers for effective teacher education programs. The present study focused on helping pre-service teachers develop their NOS views within a combination of different contextualized settings coupled with explicit reflective NOS instruction. The research question guiding the present investigation was:

How does a combination of different contextualized settings, coupled with explicit reflective NOS instruction, promote pre-service science teachers' NOS understanding?

Conceptualizing Nature of Science

Although there has been an ongoing debate on the definitions of NOS among science educators, scientists, science philosophers, and historians of science, there has been an acceptable level of generality on the definition of NOS and the content of NOS that should be taught at the K-12 level (Abd-El-Khalick, 2001; Abd-El-Khalick & Akerson, 2004). The nature of science, defined as values and assumptions inherent to development of scientific knowledge, was an agreed definition of NOS, which was accessible to K-12 students. (Lederman, Lederman, & Antink, 2013). Scientific knowledge was introduced with seven characteristics corresponding to this level of generalization (Abd-El-Khalick, Bell, & Lederman, 1998; Akerson, Abd-El-Khalick, Lederman, 2000), which were not a complementary list, but rather presented as a framework to describe NOS aside from scientific inquiry. These characteristics also described what constituted NOS in the present study. The characteristics were:

1. Empirical nature of scientific knowledge. Empirical NOS is based on and derived from observations and experiments.
2. The tentative nature of scientific knowledge. Scientific knowledge was subject to change in the light of new evidence through advances in technology or theory, reinterpretation of existing knowledge or new perspective.
3. Scientific knowledge was based on inferences and observations. This characteristic highlighted that there was a crucial distinction between observation and inference.
4. Scientific theories differed from laws. It explained scientific theories and laws as a different kind of scientific knowledge.
5. The subjective nature of scientific knowledge. It explained that although scientists look for objectivity while doing scientific investigations, it was inevitable that scientists did not undertake

scientific investigations, observations, inferences without any bias.

6. The creative and imaginative nature of scientific knowledge. It pointed out that scientific knowledge partially involved scientists' imagination and creativity.
7. The socio-cultural embeddedness of scientific knowledge. Scientific knowledge was produced within a culture and society to which scientists belong.

As the focus of this study is K-12 science pre-service teachers, it is important to enable these teachers to have an in-depth understanding of what they are expected to teach in their future teaching practice.

Pedagogical approaches to facilitate NOS understanding

Two distinct approaches, the implicit and explicit approach, have been proposed in literature that has attempted to improve NOS views. (Abd-El-Khalick, & Lederman, 2000; Schwartz, Lederman, & Crawford, 2004). Empirical evidence expressed in the literature was mostly in favor of an explicit approach to gain desirable changes in NOS views of pre-service teachers. The explicit approach adopted the assumption that improving views of NOS should be planned through objectives, instructional attention, and assessments. This approach intentionally draws learners' attention to aspects of NOS through discussions, guided reflection and specific questioning in the context of activities, investigations and historical examples. The explicit approach considers NOS understanding as a cognitive instructional outcome rather than affective one. It also has a reflective component, which enables participants to reflect on their NOS learning through structured opportunities. That is, an explicit approach is also known as an explicit-reflective approach. Empirical support has shown the effectiveness of the explicit reflective NOS to promote adequate NOS understanding (Abd-El-Khalick & Lederman, 2000; Abd-El-Khalick, & Akerson, 2004).

Explicit reflective NOS instruction may vary within a continuum of decontextualized and contextualized approaches. Decontextualized activities introduce NOS concepts explicitly without being integrated into the specific context of science t in explicit reflective NOS instruction. While, decontextualized activities might include content generic activities such as black box activities, discrepant events, puzzle solving or pictorial gestalt switches (Lederman & Abd-El-Khalick, 1998; Clough, 2006), contextualized NOS activities introduce NOS concepts in an explicit and reflective way, embedded within science content. Research suggests inquiry, history of science, and socio scientific issues and science content as contexts which provide contextualized explicit reflective NOS instruction (Bell, Mulvey, & Maeng, 2012; Bell, Matkins & Gansneder, 2011; Ozgelen, Tuzun, & Hanuscin, 2012; Rude, & Howe, 2009; Wahbeh, 2009). Although decontextualized explicit reflective NOS instruction provides learners with opportunities to revise their NOS views, without struggling with science content, these settings were not by themselves sufficient to help develop a deeper NOS understanding (Ozgelen, Hanusci, & Yilmaz-Tuzun, 2012; Rude& Howe, 2009; Seung, Bryan& Butler, 2009; Wahbeh, 2009). Highly contextualized activities within explicit reflective NOS instruction is claimed to be required for developing deeper understanding of NOS, which is transferable to new situations. (Abd-El-Khalick, 2005; Clough, 2006; Wahbeh, 2009). For instance, in one study on embodied contextualized explicit-reflective NOS approach, Rudge, Cassidy, Fulford and Howe (2013) investigated the changes in NOS views during a historically based unit. Participants of the study were 130 pre-service elementary teachers enrolled on a course of three series of lessons based upon HOS couples with explicit reflective NOS instruction. Analysis of data revealed that participants developed deeper understanding of NOS. Participants became more sophisticated related to NOS aspects such as the role of experiments and evidence. Researchers concluded that explicit-reflective NOS instruction was necessary, but use of multiple examples form HOS might help students to gain more meaningful NOS understanding. In another study undertaken with in-service teachers, explicit-reflective NOS instruction enriched with content based examples were used to improve NOS views (Wahbeh, 2009). For this purpose, inquiry based activities were provided to create opportunities to think NOS in those science contexts. Dramatic changes in in-service science teachers' NOS views were attributed to the content-rich nature of explicit reflective nature of science approach. These results were complied with the claim favouring contextualized explicit reflective settings for meaningful NOS understanding. Taking into consideration Clough (2006)'s claim stating NOS instruction within a continuum starting from decontextualized NOS instruction towards to moderate and highly contextualized NOS instruction had better support meaningful NOS understanding, the current study adopted an explicit reflective NOS teaching within a framework ranges between decontextualized activities towards to moderately and highly contextualized activities to provide pre-service teachers undergo conceptual change for NOS. It was assumed that such instruction would provide pre-service teachers with revising and refining their NOS views without struggling with any science content but would give opportunities to relate NOS to science content within a contextualized framework at the same time. Therefore, such instruction is more likely to result in conceptual change for deeper NOS understanding. Consequently, it is expected that the current investigation with pre-service science teacher would contribute to our understanding of effective instructional practices to improve teachers' NOS conceptions better.

THEORETICAL FRAMEWORK

The theoretical framework that guided this study was constructivist theory which enabled us to understand the interplay between nature of science instruction and the context. The constructivist approach states that learning is an active process in which learners constructed knowledge by themselves through adaptation and organization to the new environment (Piaget, 1976; Vygotsky, 1962). Additionally, it is claimed that construction of knowledge could not be isolated from society and culture which stressed the importance of environment during knowledge construction (Vygotsky, 1962). That is, social environment influences learning through language, tools and social institutions, thus cognitive changes are more likely come as a result of the interaction with knowledgeable social agents-peers, students develop from these social interactions (Vygotsky, 1962). Compatible with constructivist theory, explicit reflective NOS instruction within a contextualized framework might provide optimal context for developing in-depth NOS views by featuring small group discussions regarding NOS aspects and reflection opportunities related to ones' own conceptions of NOS.

METHOD

Present study was an interpretive qualitative research (Merriam, 2009) focused on meanings that participants ascribed to the emphasized NOS aspects. The main focus of the study was to explore pre-service science teachers' understanding of NOS within a contextualized explicit reflective NOS based approach. Specifically, the present study aimed to investigate following research question: How does combination of different contextualized settings coupled with explicit reflective NOS instruction promote the pre-service science teachers' NOS understandings?

Participants and Context of the Study

Participants were volunteered seven pre-service science teachers enrolled in science method course offered in fall semester in the department of elementary education in the one of the biggest university in Turkey. All participants were senior students and at their fifth semester of science teacher education program.

The study was undertaken through an elementary science methods course. The course consisted of 3 hours of theory session and 2 hours of practice session. In the theory session participants were introduced major concepts of the topic. The practice session of the course was held for 2 hours in a week. Participants were intensively engaged in discussions, hands-on activities and reading assignments in weekly held 2 hours practice sessions. The aim of the elementary science method course was to provide participants with theoretical framework for teaching science at elementary level, and with desired attitudes toward science and science teaching as well as deeper understanding of nature of science. It included hands-on activities, readings activities and assignments, to provide insights on scientific literacy, science process skills and nature of science. Another important task of the course was lesson plan preparation.

Intervention

In present study explicit-reflective NOS instruction was undertaken both through decontextualized and contextualized activities for 10 weeks within the science method course. First, participants were exposed to decontextualized NOS activities for the first four weeks. During intervention, pre-service science teachers were firstly introduced the related concepts such as definition of science, and who are scientists through an interactive discussion through providing them with the stereotypical image of scientists. Additionally, the difference between science and non-science had been discussed through hands-on/minds on activity which was "knowledge claim statements (Scharman, Smith, James, & Jensen, 2005) in present case. That is, participants were supposed to place some claims on a continuum from less scientific to more scientific. In addition to these, the activities of "Tricky tracks", "Young? Old?", "The aging president", "Real fossil real science", "An activity for the first day of class" (Choi, 2004), "Sequencing events", and "Black box" served to address the difference between observation and inference, the empirical basis of scientific knowledge, imaginative, subjective and tentative nature of scientific knowledge. The details of the activities could be found somewhere else (Lederman & Abd-El-Khalick, 1998).In addition to these, the function of theories and laws were emphasized during the activities explicitly. Through the activities participants were presented each targeted NOS aspect through explicit reflective NOS instruction. That is, participants were encouraged to discuss and reflect their ideas about the related NOS issue. After each activity, main targeted NOS issues were emphasized either orally or through creation of NOS charts by the instructor enabling participants to pay attention to their unclear NOS ideas. All activities were chosen purposefully to be content generic to encourage participants to focus on NOS content rather than specific science content. The outline of decontextualized NOS activities was summarized in Table 1.

Table 1 Outline of decontextualized nature of science activities

Course weeks	Activities	Targeted NOS aspect
1st week	Draw a scientist	Introduction of major concepts such as science, scientists, how scientists work
	Knowledge claim statements	Limits of science and what makes our knowledge be scientific.
2nd week	Card exchange activity	Introduction of major concepts such as science, scientists, how scientists work
	Tricky Tracks	Difference between observation and inference Subjective nature of scientific knowledge
	Young? Old The Aging President	Subjective nature of scientific knowledge Difference between observation and inference Social cultural embeddedness
3rd week	Real fossil real science	Role imagination and creativity in development of scientific knowledge, Empirical basis of scientific knowledge, Role of scientists' inference in development of scientific knowledge Subjective nature of scientific knowledge
	An activity for the first day of class	Influence of scientists' subjectivity on scientific knowledge, Tentative nature of scientific knowledge Role imagination and creativity in development of scientific knowledge Function and definition of theory and laws.
4th week	Sequencing Events	Empirical basis of scientific knowledge, Subjective nature of scientific knowledge, Socially culturally embeddedness,
	Black Box	Function and definition of theories and laws Empirical basis of scientific knowledge Subjective nature of scientific knowledge Tentative nature of scientific knowledge Role imagination and creativity in development of scientific knowledge

To contextualize science method course for more effective NOS instruction, practice session of method course utilized activities and readings including HOS components. Such that, conflicts, controversies and personalities of scientists which influenced scientists work through a discovery of a scientific concept were used to create discussion environment to clarify NOS aspects explicitly. In general, each week started with a reading script including HOS example followed by lesson plan presentations. These reading scripts served as a warm up part to initiate discussion on NOS and clarify NOS concepts better. The brief description of the each reading script with targeted NOS aspects was presented in Table 2.

Table 2 Brief description of History of science scripts

Reading script	Description of the script	Targeted NOS aspect
The changes in conceptions of freezing, melting points from “Science in Action”, by John Lenihan, (1990)	That script mentioned about the development of terms such as melting point, and freezing points.	Empirical NOS Inferential NOS Creative NOS Tentative NOS
Double Helix by James Watson (1968)	It was related to earlier thought about DNA, and how James Watson started to be interested in structure of DNA	Socio-cultural NOS Subjective NOS Tentative NOS
Double Helix by James D. Watson (1968):	That script was related to role of Rosalind Franklin in discovery of DNA	Socio-cultural NOS
Discovery of Current Electricity (http://learningscience.edu.hku.hk/Package.html)	The script related to two different approaches adopted by two different scientists Luigi Galvani and Alessandro Giuseppe Volta.	Subjective NOS Tentative NOS Empirical NOS Inferential NOS

Moreover, these examples gave ideas related to approaching a HOS based example regarding how to analyse an example in terms of NOS aspects, what kind of examples to include in lesson plans, and how to integrate these examples into lesson plans and their teaching. Last of all, the purpose of these examples was two folded such improving the NOS understanding as well improving NOS teaching. After each HOS based example following questions were asked to highlight NOS aspects:

I. What does this script have to do with science?

II. Which aspects do you think might have been reflected through this reading and why/how (in which ways)?

Each of these HOS reading script was followed by lesson planning activity. Lesson planning activity as whole was consisting of lesson plan preparation and presentation. Pre service science teachers were required to prepare 5 lesson plans (one for each week) on the one of the science topics selected from science and technology curricula across grade K 6-8. Then, each week one volunteer participant presented his/her lesson plan to the class. Each microteaching of the lesson plan was followed by group discussion. These discussions were aimed to provide participants with opportunities articulate meanings of various NOS aspects and to internalize these aspects. After each presentation of lesson plans following questions were asked as prompts to trigger discussion on NOS concepts:

III. Which NOS aspects were presented through the lesson plan presentation?
IV. Do you think these NOS aspects are presented adequately?

Lesson planning activity provided opportunities to pre-service science teachers to engage in science curricula for NOS integration. Additionally, it provided contextualized NOS learning environment enabling pre-service science teachers refine and revise their NOS views. Therefore, lesson planning activity was assumed to be a highly contextualized framework for explicit reflective NOS approach since it required integration of NOS directly in science content. The outline of contextualized activities was presented in Table 3.

Table 3 Outline of the contextualized activities

Week	Contextualized activities
6th week	• Contextual example: Reading exempt about changes in conceptions of freezing, melting points from Science in action by John Lenihan • Lesson plan preparation and presentation
7th week	• Contextual example: Reading exempt from Double Helix by James Watson • Lesson plan preparation and presentation
8th week	• Contextual example: Reading exempt about Rosalind Franklin from Double Helix by James Watson • Lesson plan preparation and presentation
9th week	• Contextual example*:* Discovery of Current Electricity • Lesson plan preparation and presentation
10th week	• Discussion on Lesson plan preparation • Lesson plan preparation

Data Sources and Analysis

In order to determine teachers' NOS views, modified version of the views of nature of science questionnaire, form C (VNOS-C) was administered in conjunction with semi structured interviews to provide validity of the instrument (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). All participants responded the questionnaire twice over the science method course as at the beginning of the science method course and at the end of the science method course. The questionnaire was modified by adding some additional questions from other VNOS questionnaire forms (e.g. VNOS B, VNOS D+). The need for modification of the VNOS-C was determined by me as a researcher based on my past NOS research experiences with pre-service science teachers. I believe that, modification enabled to get more detailed responses from the participants. As a modification, I split up some questions in two or add some additional follow-up questions which would provide more detailed responses. Through the current research, participants' views about (a) empirical nature of science (b) subjective nature of science, (c) tentative nature of science (d) role of creativity and imagination in development of scientific knowledge, (e) inferential nature of science, (f) socio cultural embeddedness of scientific knowledge and (g) the function and definition of theories and laws were considered. The interviews related to VNOS-C responses were used to validate participants' responses to open ended questionnaire (VNOS-C) as suggested by the developers of the questionnaire (Lederman et.al., 2002). It was conducted at the beginning and end of the science method course as pre-and post-interviews. Of the five participants were agreed to interview at the beginning of the science method course and all of the participants volunteered to interview at the end of the science method course.

All pre-and post- VNOS-C responses were analysed to generate pre and post instruction profiles of participants' NOS views. The data analysis included writing reflective notes in passages, drafting a summary sheet, writing codes, creating patterns and themes, counting for frequency of codes, relating categories and making contrast and comparisons (Miles & Huberman,1994). Two researchers -I as a researcher and another NOS expert independently analysed pre-post VNOS-C responses of three participants' responses. These analyses were compared, with any differences resolved through discussion. At the end, both researchers were agreed on the NOS views categories which constructed the NOS profiles of the participants for the present study. Analyses of VNOS-C questionnaire results were entailed transcription and coding of the interview responses. Three types of categorization were used as "informed" (I) "adequate" (A) and "inadequate" (IA). The views were categorized as either "informed" (indicating a fully developed understanding of the NOS aspect including extended examples and deeper explanations), "adequate" (indicating a developing/acceptable view but with lack of deep explanations or examples), or "inadequate" (indicating a misconception or not aligned view with contemporary science reforms was held by the student). The differentiation between "informed" view and "adequate" view was made based on overall NOS explanations, such as references to class activities as well their own examples, details of examples and deepness of their explanations.

FINDINGS

Data analysis indicated that participants revealed a substantial improvement in their NOS views. None of the participant held inadequate view of any NOS aspect at the end of the science methods course. More dramatic change occurred regarding the understanding of the role and function of theories and laws and socio-cultural NOS aspects. All participants held misconception related to hierarchical order between theories and laws, and "universal" science. At the end, all of the participants achieved improved understanding the functions of theories and laws and socio-cultural NOS. Similarly, six of the participants held inadequate understanding of subjective and tentative NOS at the beginning of the science method course. All of the participants improved their views as informed understanding of tentative and subjective NOS at the end of the science methods course. Total of the five participants held inadequate views of empirical NOS prior to NOS intervention. At the end of the NOS intervention, five of the participants developed their views such that all of them displayed informed understanding of empirical NOS. Two of the participants who held inadequate understanding of empirical NOS initially, developed their understanding towards adequate empirical NOS view as well. Regarding creative NOS, three participants held adequate understanding and four participants had inadequate understanding of creative NOS. All participants shifted their creative NOS understandings towards informed view at the end of the intervention. Surprisingly, almost half of the participants indicated adequate understanding of inferential NOS at the beginning of the NOS intervention. At the end of the NOS intervention, six of the participants achieved informed understanding of inferential NOS, whereas only one participant holding inadequate view of inferential NOS achieved adequate inferential NOS view. To sum up, all participants achieved mostly informed views of NOS for various aspects at the end of the science methods course. None of the participants revealed inadequate understanding for any NOS issues at the end of the NOS intervention. Following Table 4 indicated participants' pre- and post- NOS views with regard to each aspect over the science methods course:

Table 4 Participants' pre- and post-NOS views over NOS intervention

	Tentative NOS		Empirical NOS		Inferential NOS		Creative NOS		Social-cultural NOS		Theory& Law		Subjective NOS	
Participants	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre
Safa	I	IA	I	A	I	A	I	IA	I	IA	I	IA	I	IA
Lale	I	IA	I	IA	I	A	I	IA	I	IA	I	IA	I	IA
Lia	I	A	I	A	I	A	I	A	I	IA	I	IA	I	NC
Simge	I	AI	I	IA	I	A	I	IA	I	IA	I	IA	I	IA
Ebru	I	IA	A	IA	I	IA	I	IA	I	IA	I	IA	I	IA
Melis	I	IA	I	IA	I	IA	I	A	I	IA	I	IA	I	IA
Esin	I	IA	A	IA	A	IA	I	A	I	IA	I	IA	I	IA

IA: Inadequate; A: Adequate; I: Informed; NC: Non categorized

Below, we described change in NOS understanding for each NOS aspect. Excerpts and quotations from participants' responses were used to illustrate major categories.

Change in Tentative NOS views:

Prior to contextualized intervention, only one participant held adequate view of tentative NOS. He was able to articulate that science is subject to change for all kind of scientific knowledge including scientific laws. However, his responses related to tentative NOS lacked of detailed explanation such that he did not explain how/ why scientific knowledge changes:

> *P#3 It [scientific knowledge] changes because the development in science brings change which results in investigating different aspects. It is feature of life and knowledge. To illustrate this [tentative nature of scientific knowledge] Newton's law of motion which is x=v.t is valid in between 1700- 1900's but it is changed by Einstein's Relativity theory after 1930's.*

Of the six of the participants showed inadequate understanding of tentative NOS. In these participants' responses to pre-VNOS-C, they indicated that science is subject to change due to new evidence and technological improvements but they did not apply her view for the change of laws. Therefore, their views were categorized as inadequate:

P#1 I think this knowledge [scientific knowledge] may change in future because technology and knowledge develop. Therefore, people can find other things [new scientific knowledge] for science in the future and knowledge may change. For example, people [scientists] thought that there is no life in Mars but now, scientists develop their knowledge about life on Mars… Law is supported and proved; it never changes…

P#6 Laws cannot be changed. Theory can be changed. Theories cannot be changed, when they turn into laws. For instance, evolution theory can be changed.

Post VNOS-C analyses revealed substantial improvements in participants' tentative NOS views.

All participants' tentative NOS views were categorized as informed view. To be able to have informed tentative NOS view, one need to recognize that all kind of scientific knowledge is subject to change with the new evidence, advancement in technology and reinterpretation of scientific knowledge. For instance, following participants recognized scientific knowledge could change with new evidence and also she outscored both theories and laws could change with new evidence and technological enhancements:

P#4…when new traces [evidence] found or revised scientific knowledge can be developed, modified or changed completely…For instance, scientific laws and theories could be modified or changed completely because of improvements in technology and new improvements.

Change in Empirical NOS views:

Total of the five participants held inadequate views of empirical NOS and two of them displayed adequate understanding of empirical NOS prior to NOS intervention. majority of the participants holding inadequate empirical NOS views were not to be able to differentiate science from other disciplines by means of empirical NOS. That is, they differentiated science from other disciplines by means of easing people's life rather than requirement of an evidence, observation or testable procedures:

P#2[Regarding how science is different from other disciplines] science is more concrete and helpful for people; in science, one [scientists] could find a medicine which is useful for people.

Participants who held adequate views of empirical NOS initially recognized that science is a testable procedure including observations and experiments but with lack of detailed explanation and examples:

P#3 Science is different from other disciplines by its aspects of to measure and having valid result that affect life of all living organisms…Actually, it [science] is set of experiments and observations…

At the end of the NOS intervention, five of the participants developed their views such that all of them displayed informed understanding of empirical NOS. They she appreciated role of evidence as prerequisite to make claims, and support scientific explanations and they also highlighted evidence to differentiate science from other disciplines at the end of the NOS intervention:

P#6 NOS make science different from other disciplines…. For example, in science we support our ideas with experiments or observations… [in science] data is gathered through experiments and they are inferred. We have evidence [in science]. …. however, in religious or philosophy we cannot support our ideas such as existence of God.

Two of the participants who held inadequate understanding of empirical NOS initially, developed their understanding towards adequate empirical NOS view as well.

Change in Inferential NOS views:

Almost half of the participants indicated adequate understanding of inferential NOS whereas three participants showed inadequate understanding of inferential NOS at the beginning of the NOS intervention. The ones holding the inadequate view of inferential NOS believed that believed that science is "what we see", and they failed to recognize that scientists actually make sense of "what they observe". That is, they held the view that natural phenomena were directly accessible to the human senses:

P#6. [to decide existence of dinosaurs] They [scientists] proved the existence of dinosaurs with finding and examining fossils.

P#7[to decide the existence of dinosaurs] They[scientists] are do research, find fossils under the stones which enable them[scientists] to prove that once dinosaurs had lived.

Majority of the participants holding adequate view of inferential NOS were aware of that scientists make inferences, but they did not provide detailed explanations or examples:

P#3 [To decide dinosaur's existence] scientists examine some remaining that belongs to animals. Also they make research on DNA.

At the end of the NOS intervention, six of the participants achieved informed understanding of inferential NOS, whereas only one participant holding inadequate view of inferential NOS achieved adequate inferential NOS view. Following excerpts illustrated participants informed views of inferential NOS:

P#1 For example, scientists cannot do experiments about the solar system. Scientists make inferences derived from observations… [to determine existence of dinosaurs] Scientists made some research and found fossils. With respect to these fossils, they [scientists] make inferences.

P#3[to decide dinosaur's existence] They gather some data like fossils and they infer that these fossils do not belong to any organism that known by scientists. Therefore, they refer to a different animal now known as dinosaurs.

Change in Creative NOS views:

Regarding creative NOS, four participants held inadequate understanding and three participants had adequate understanding of creative NOS. The ones who held inadequate creative NOS understanding believed that science was as an activity only depended on experiments and scientists' imagination would impair their objectivity.

P#5…there should not be any imagination [in science] which can only depend on experiment in science…. Scientists do not use their imagination and creativity in science so that, they become objective.

P#4 No [regarding the role of scientists' imagination and creativity in scientific investigations]. They [scientists] are [only] collecting data, making experiments and calculate the results in order to confirm their hypothesis.

The participants who were categorized as having adequate creative NOS views recognized the recognized role of scientists' creativity and imagination in development of scientific knowledge but mostly in particular stages of the scientific investigation.

P#3 I think they [scientists] use their imagination and creativity in all steps [of scientific investigation] because in any steps they have unknown results. But mostly, it is the planning stage [of scientific investigation] that they [scientists] use imagination and creativity.

All participants shifted their creative NOS understandings towards informed view at the end of the intervention. They all appreciated that scientists used their imagination at all parts of the scientific investigation and supported their claim with examples or detailed explanations. Following excerpts elucidated participants' informed creative NOS views:

P#4...they [scientists] use their creativity and imagination while constructing the dinosaur [model]...Scientists use their imagination and creativity at almost every stage of the scientific investigation. For instance, two different scientists could collect different kind of data and design different kind of experiments on same issue.

P#7…. Scientist uses their imagination and creativity in every part of investigation. For instance, in the black box experiment we saw this. You don't know what is inside, you observe and you use your imagination to figure out what is going on inside the box.

Change in Socio-cultural NOS views:

At the outset of the NOS intervention all participants held the misconception of "universal" science. They all stated science as universal and free from cultural norms in which science practiced at the beginning of the intervention in their responses to pre-VNOS-C:

P#7 Science is universal...Science is not affected by culture, history, political values etc…..

P#1 Science is universal; it should not be affected by socio- cultural values. We think that scientists are objective. Thus, scientists should not be affected [by values and norms of culture].

All participants shifted their inadequate socio-cultural NOS views towards informed views at the end of the intervention. All participants recognized science as a discipline influenced by culture's norm and values and also provided a detailed explanation or an example to support their view:

> *P#2 Scientific knowledge can be affected by social cultural values. Because scientists' knowledge can be shaped by his/her experiences and beliefs. Problems of society in which scientists live affect their work. Because scientists did some research to solve these problem. For instance, pig flu [A(H1N1) virus] is on the agenda nowadays, so scientists are working on it [pig flu virus] more intensely to solve the problem.*

> *P#5Science reflects socio cultural values. Because scientists are human beings. It is impossible that, they are not affected their culture and society which they live in. Even their expertise fields are determined by their culture. For example, in Turkey, working about evolution is not very easy and the number of scientists who work about evolution is very low. This is due to the religion in Turkey*

Change in Theory & Law views:

At the beginning of the intervention, all participants held misconception related to hierarchical order between theories and laws. Mostly they believed that believed that there was a hierarchical order between theories and laws and theories became law after they were proved:

> *P#2 if the scientists conclude that his/her hypothesis is true with experiments' this hypothesis becomes theory. .... If theories are proved, this theory becomes a law and it never changes…*

However, participants revealed a dramatic change in their views related to the theories and laws at the end of the intervention. All of them could be able to explain the role and functions of theories and laws, and gave detailed explanation on theories and laws in addition to supporting their explanations with examples:

> *P#7 Theory is explanations about observable phenomena. Theory can change through time. ...Law is the information that states the relationship between observable phenomena. They can also change with new information … For example atom theories give examples [explanation] related to structure of an atom. But Newton's law gives [indicate] relationship among force mass and acceleration.*

> *P#1 Theory is an explanation of scientific phenomena. Theory may change over time…. Law is definition of relationship between phenomena. A law may change... [Regarding difference between*

theory and law] For example, the modern atom theory explains the properties of atom but the first law of gravitation defines the relationship between the matter and force.

Change in Subjective NOS views:

Of the six participants held inadequate understanding of subjective NOS at the beginning of the science method course. To be considered as holding inadequate view related to subjective NOS, one needs to indicate that science is a way for searching truth, as well as scientists' pre-conceptions and beliefs do not influence the scientific knowledge they produce. Following excerpts illustrated participants' inadequate views of subjective NOS:

P#7 [regarding existence of different theories on extinction of dinosaurs] I guess they [scientists] have not had enough data so they cannot prove why dinosaurs become extinct…They do not have enough knowledge.

P#2[regarding extinction of the dinosaurs] There are a lot of reasons such as volcano, exposure to earthquakes and separation of continents for extinction of living things. Because this events occurs 65 millions of years ago scientist could not sure about the reason of extinction of dinosaurs….

All of the participants improved their views as informed understanding of tentative and subjective NOS at the end of the science methods course. That is all of them could be able to articulate that scientists' interpretations would vary because of personal backgrounds, perceptions, pre conceptions and expectations by providing detailed explanation at the end of the NOS intervention. Following excerpts indicated participants' informed views of subjective NOS revealed in their post-VNOS-C responses:

P#1 The explanations [on the same topic] in science may differ because scientists are affected by their prior knowledge, creativity, social and cultural conditions…. They interpret data differently because of these differences …For this reason, despite using the same information [data], they may disagree on a topic.

P#5 Each scientist has his/her own prior knowledge, training, creativity, experience and expectations. Due to these differences their conclusions are different from each other's although they all have same information. This is the subjectivity aspect of NOS.

DISCUSSION AND IMPLICATIONS

The current study showed that, contextualized explicit reflective NOS instruction combined various contexts were influential to gain desired understanding of NOS. The content- rich context embodied science content, HOS and decontextualized NOS activities increased the effectiveness of explicit-reflective NOS instruction resulted in informed views of pre-service science teachers. Findings of the study revealed substantial improvements in pre-service science teachers’ NOS views regarding creative, inferential, socio-cultural, empirical, subjective NOS as well as function and definition of theories and laws in this study at the end of the contextualized explicit reflective NOS intervention. Majority of pre-service science teachers shifted their inadequate NOS views towards informed views as a result of the contextualized explicit reflective NOS intervention. These positive results of the study in relation to developing favourable NOS conceptions have showed effectiveness of the contextualized explicit reflective NOS instruction as indicated previous studies (Abd-El-Khalick, & Akerson, 2009; Akerson, & Donelly, 2008; Bell, Matkins, & Gansneder, 2011). The substantial contribution of the explicit reflective NOS instruction to the development of pre-service science teachers’ NOS views was attributed to the setting of the explicit –reflective NOS instruction in the present study which integrated range of decontextualized and contextualized explicit reflective NOS activities as suggested by Clough (2006).The current study embodied decontextualized NOS activities first, which enable pre-service science teachers to understand their initial NOS concepts, revise their concepts, and reflect on their relative status of these concepts without pressure of understanding of science concepts (Abd-El-Khalick& Akerson, 2004). Since decontextualized NOS activities were found to be limited to gain deeper NOS understanding (Abd-El-Khalick, 2001), explicit reflective NOS instruction continued with various contextualized opportunities for pre-service science teachers to develop meaningful NOS understanding. HOS has been chosen to provide contextualized opportunities for pre-service science teachers in the present study. For instance, pre-service science teachers were provided with examples from HOS highlighting all the relevant NOS aspects. They were encouraged to think how these examples from HOS reflected specific NOS aspects. Throughout these examples, they also had a chance to revise their NOS conceptions through various settings such as life of scientists, and important scientific discoveries within HOS. In parallel, HOS was claimed to serve as an effective way to contextualize NOS instruction because historical examples related to science aided as specific reference to NOS tenets by some researchers (Abd-El-Khalick, 2001; Clough, 2006; Howe & Rudge, 2005). It was also claimed that HOS provided learners with opportunities not only to learn issues relating to NOS but also science content (Clough, 2006; Howe & Rudge 2005; Paraskevopolou & Koliopoulos, 2011).

In addition to HOS context, the current study also provided science content as a context to revise and refine NOS ideas. By means of science content, the pre-service science teachers were involved in specific pedagogical practices such as planning, presenting and discussing NOS lessons which were supposed to prepare as integrated to K-12 science content explicitly and reflectively. These specific pedagogical practices provided pre-service science teachers with structured opportunities to reflect on their NOS conceptions and also assess their NOS conceptions in the context of science content. For example, while designing NOS lessons, pre-service teachers needed to revise their NOS conceptions to be able to integrate these concepts into their lesson plans within science content from elementary science curriculum. For instance, participants were expected to design a lesson e.g. for atom models and integrate NOS explicitly and reflectively at the same time. To be able to do so properly, participants needed to comprehend NOS in the context of atom models and embedded NOS accurately. This process required pre-service science teachers to scrutinize their NOS concepts in-dept. Furthermore, presentation of lesson plans followed by class discussions helped pre-service science teachers revisit their NOS concepts which resulted in deeper understanding of those NOS aspects. In sum, this content- rich context embodied science content and HOS contributed to the effectiveness of explicit-reflective NOS instruction, which resulted in informed views of pre-service science teachers as suggested by other researchers (Abd-El-Khalick, & Lederman, 2000; Abd-El-Khalick, 2001; Abd-El-Khalick, & Akerson, 2004; Clough, 2006; Deniz, 2007; Schwartz, & Crawford, 2004).

While teaching NOS, the main goal is having learners with meaningful deeper understanding of NOS rather than rote memorization of NOS tenets. That is, learners could be able to understand various aspects of NOS and show that understanding within different contexts through examples and extended explanations of these aspects. Providing learners that kind of understanding necessitates teaching NOS within variety of contexts coupled with explicit reflective NOS approach. Our study calls attention to the need to examine the specifically contribution of each context to the NOS understanding.

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