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Exploring the Development of Preservice Science Teachers' Views on the Nature of Science in Inquiry-Based Laboratory Instruction

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Abstract The purpose of this study was to explore the effect of the inquiry-based and explicit–reflective laboratory instruction on preservice science teachers' (PSTs) conceptions of the nature of science (NOS) aspects. This study was carried out during the Laboratory Application in Science II course. All 52 preservice elementary science teachers enrolled in the course consented to participate in the study; 37 were female and 15 were male, with a mean age of 22.8 years. All had the same science major background, and all of them were juniors. The course provided meaningful and practical inquiry-based experiences, as well as explicit and reflective instruction about NOS. Each week, a specific NOS aspect was targeted related to the inquiry-based laboratory investigation. The design of the study was qualitative and exploratory in nature. At the beginning of the study, the Views of Nature of Science Questionnaire Version B open-ended questionnaire was applied to explore PSTs' NOS views. At the end of the semester, the same questionnaire was conducted to determine the impact of the explicit–reflective and inquiry-based laboratory instruction. The results showed that many PSTs improved their views of NOS in each element, although to different degrees.

Keywords Nature of science · Preservice science teacher education · Inquiry-based laboratory instruction

Introduction

In general, scientific literacy is related to helping individuals adjust to life in modern society. Due to the changing nature of societal issues, scientific literacy has had a wide variety of definitions since it was first introduced in the late 1950s (DeBoer 2000). Despite this

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variation, there is a consensus among educators about the importance of scientific literacy (Bybee 1997). The National Science Teachers' Association (NSTA) identified scientific literacy as the main purpose of science education for *all* students, not just those pursuing careers in science and engineering. The NSTA defines a scientifically literate person as one who "uses science concepts, process skills, and values in making everyday decisions as he interacts with other people and with his environment" and also who "understands the interrelationships between science, technology and other facets of society, including social and economic development" (NSTA 1971, pp. 47–48). This underscores the importance of the nature of science (NOS) and scientific inquiry (SI) to developing scientific literacy (National Research Council [NRC] 1996). In this study, we proposed and investigated a means to improve the understanding of NOS using SI skills in the context of preservice science teacher (PST) education.

Nature of Science

Understanding NOS is an essential component of scientific literacy (Bybee and DeBoer 1994) and is one of the most commonly declared objectives for science education (American Association for the Advancement of Science [AAAS] 1993; NRC 1996). In the literature, NOS has been defined in numerous ways by different researchers (e.g., Alters 1997; McComas and Olson 1998), but in general refers to the "values and underlying assumptions that are intrinsic to scientific knowledge, including the influences and limitations that result from science as a human endeavor" (Schwartz et al. 2004a, b, p. 611).

In this study, we relied on a list of NOS aspects believed to be relevant to K-16 education (Abd-El-Khalick and Akerson 2004; Lederman et al. 2002; Schwartz et al. 2004a, b). These include empirical NOS, tentativeness, subjectivity, creativity, social–cultural embeddedness, and the relation between observation–inference and theory–law.

Scientific Inquiry

SI is defined as a multifaceted activity that involves observations, inferences, formulating hypotheses, designing investigations, defining variables, collecting data, and interpreting and communicating results (NRC 2000). Inquiry-based instruction emphasizes the use of the science process skills (SPS), such as observation, collection of data, experimentation, etc., in gaining scientific knowledge, which are integrated into the broader abilities of SI. Therefore, the standards include the "process of science" and require that students combine SI and scientific knowledge, this allows students to understand scientific concepts and NOS aspects. SI refers to characteristics of the scientific enterprise and the methods that guide the development of scientific knowledge (Schwartz et al. 2004a, b). Although science reforms promoted student engagement in inquiry, research has shown that this alone is not sufficient for learners to develop an understanding of NOS (Khishfe and Abd-El-Khalick 2002). Although students can develop their process skills during inquiry-based instructions, developing NOS views is a different task and it needs some special methods. Therefore, in recent studies, researchers enriched their inquiry teaching environments using different methods, such as explicit and reflective instructions (e.g., Schwartz et al. 2004a, b). Through the new research approach, researchers further suggested the need of utilizing a more involved and active learning environment for better developing students' NOS understanding. This suggestion was already considered by some researchers who focused on the science laboratory to develop students' NOS understanding (Yacoubian and BouJaoude 2010). In the context of preservice teacher education, many studies have taken place in the context of science method courses (Abd-El-Khalick and Akerson 2004; Akerson et al. 2000). In the current study, science laboratory course and inquiry approach was combined in the context of PSTs' education to improve their NOS understanding.

Teaching NOS and Inquiry-Based Science Laboratory

According to Abd-El-Khalick and Lederman (2000) and Lederman (1992), most of the research during the 1960s and the 1970s revealed that many science teachers had inadequate NOS conceptions. Similar results were found during the 1980s and the early 1990s as well. Turkish preservice teachers have been found to possess inadequate conceptions about NOS, similar to US preservice teachers (Akgul 2006; Celik and Bayrakceken 2006; Tasar 2006; Yalvac et al. 2007). As a result, researchers applied different teaching methods to improve learners' NOS understandings (Abd-El-Khalick and Lederman 2000).

Two general approaches have been undertaken to improve NOS views (Abd-El-Khalick and Lederman 2000; Lederman 2007). The explicit–reflective method is defined as an "… approach [that] emphasizes student awareness of certain NOS aspects in relation to the science-based activities in which they are engaged, and student reflection on these activities from within a framework comprising these NOS aspects" (Khishfe and Abd-El-Khalick 2002, p. 555) In contrast, the implicit approach assumes NOS understanding to be a by-product of using SPS and doing activities. In general, research has shown an explicit–reflective approach to be more effective than an implicit approach in improving NOS views among in-service teachers and PSTs (Abd-El-Khalick and Lederman 2000; Lederman 2007).

Many studies to develop NOS views have been undertaken in the context of science methods courses (Abd-El-Khalick and Akerson 2004; Akerson et al. 2000). However, Akerson et al. (2000) suggested that methods courses might not be the most favorable contexts to develop science teachers' NOS understanding and that "…the explicit–reflective approach to NOS instruction embedded in the context of learning science content would not only facilitate developing science teachers' NOS views, but might go a long way in helping teachers translate their understandings into actual classroom practice" (p. 297). Furthermore, they emphasize that "…involving learners in science-based inquiry activities can be more of an explicit approach if the learners were provided with opportunities to reflect on their experiences from within a conceptual framework that explicates some aspects of NOS" (p. 689). Similarly, Lederman (2007) stressed that "…NOS is best taught within a context of scientific inquiry or activities that are reasonable facsimiles of inquiry. That is, inquiry experiences provide students with foundational experiences upon which to reflect about aspects of NOS" (p. 835).

Laboratory courses have been an important part of science education (Garnett and Hacking 1995) and play a key role in enhancing students' understanding of science concepts, as they provide suitable environments to develop scientific process skills and problem-solving abilities (Hofstein and Mamlok-Naaman 2007; Lunetta 1998). Tobin (1990) emphasized that "…laboratory activities appeal as a way to learn with understanding and, at the same time, engage in a process of constructing knowledge by doing science" (p. 405). Moreover, many educators agreed that meaningful learning in science cannot be achieved without practical experiences and that science laboratories are best for the required practical experiences (e.g., Hofstein and Lunetta 1982, 2004; Hofstein and Mamlok-Naaman 2007; Tobin 1990). Recently, the NRC prepared a report for the National Science Foundation, *America's Lab Report: Investigations in High School Science* (NRC 2005). The report emphasized opportunities for students to learn about both the process and the content of science through laboratory experiences as being essential. In this report, developing students' NOS understanding was accepted as one of the important goals for laboratory instruction (NRC 2005). Moreover, new standards for science teaching (NRC 2000) proposed applying inquiry-based laboratories to grow scientifically literate people because this type of course gives students a chance to ask questions, develop hypotheses, conduct experiments, and share and discuss results (Hofstein and Mamlok-Naaman 2007).

There are four main styles for laboratory instruction, these are (1) traditional expository, (2) discovery (guided inquiry), (3) problem-based, and (4) inquiry (open inquiry) (Domin 2007). These styles are different in terms of their outcomes, approaches, and procedures. Studies showed that inquiry-based laboratory activities including NOS aspects implicitly do not support students' NOS understanding (Abd-El-Khalick and Lederman 2000; Khishfe and Abd-El-Khalick 2002). In the present study, open inquiry-based laboratory instruction was applied and NOS aspects explicitly addressed.

Science Curricula and Science Teachers

Following major reforms (NRC 1996), many countries (Canada, USA, Australia, South Africa, UK, New Zealand, and Turkey) inserted NOS in their science curricula (Lederman 2007). For example, the Turkish elementary science curriculum was redesigned to include goals and objectives related to NOS (Ministry of National Education in Turkey [MoNE] 2004) and the science course of study was renamed as science and technology. The vision of the new science and technology curriculum is to raise scientifically literate students throughout their schooling life (MoNE 2004). Moreover, in the new science and technology curriculum, the science concepts are learned through considering technology, society, and environment relationships. The science and technology course aims to increase students' science literacy by enabling them to master seven issues. These issues are (1) the NOS and technology, (2) key science concepts, (3) SPS, (4) the relation of science, technology, society, and environment, (5) scientific and technical psychomotor skills, (6) the values constructing the essence of science, and (7) attitude and values toward science (MoNE 2004). In accordance with these dimensions, the new Turkish elementary science and technology curriculum aims to enhance students' understanding of NOS and develop their SPS.

Ultimately, the goals and objectives regarding NOS understanding in the new science and technology curriculum cannot be achieved without teachers' efforts. Research has shown that teachers' actions affect students' learning in class and that learners' gains are not independent of teachers' NOS understandings (Lederman 1992). In order to teach NOS, science teachers should have adequate experiences and understandings of NOS during their education. In this study, we examined how laboratory courses can play a role in supporting preservice teachers' understanding of NOS. Our main research question was "To what extent does an explicit and reflective approach, when implemented in the context of inquiry-based laboratory instruction, develop PSTs' understandings of NOS?"

This study aimed to explore the understandings of PSTs' NOS aspects during the explicit–reflective and inquiry-based laboratory instruction. Different strategies and approaches were applied to support opportunities for prospective teachers to experience, reflect, and discuss NOS aspects during interventions (Irez and Cakır 2006). While previous studies have explored the effectiveness of the explicit and implicit way of teaching NOS, little is known about the effectiveness of explicit instruction when applied in instructional contexts other than method courses (Lederman 2007). Therefore, this study has the potential to contribute to the NOS literature by investigating the explicit–reflective instruction applied in the context of an inquiry-based laboratory course for PSTs.

Past studies, especially focused on middle and high school levels, showed that explicit–reflective discussions after inquiry-based laboratory activities supported the development of students' conceptions of NOS (Griffiths and Barry 1993; Khishfe and Abd-El-Khalick 2002; Carey et al. 1989; Yacoubian and BouJaoude 2010). Similarly, explicit–reflective and activity-based instruction has been shown to enhance preservice elementary teachers' views of NOS. Akerson et al. (2000) used a set of activities to develop preservice elementary teachers' NOS views. They found that this approach was effective to develop participants' understandings of some NOS aspects, but not all of the NOS aspects. Meichtry (1999) used real science experiences to improve preservice teachers' NOS views and suggested inquiry-based teaching with real experiences. In addition, many researchers used the explicit–reflective approach and content-generic activities in science method courses (Lederman and Abd-El-Khalick 1998).

Despite these promising findings, research continues to show that teachers struggle to understand NOS (Akerson and Hanuscin 2007) and that changes in students' understanding of NOS may not be retained long-term (Akerson et al. 2006). Educators have stressed a lack of emphasis on NOS across prospective teachers' programs as a reason for this limited achievement and emphasize that teaching NOS should engage in not only pedagogy courses but also science content courses (Abd-El-Khalick and Lederman 2000).

Brickhouse et al. (2000) focused on an introductory astronomy course as a context for improving undergraduates' understanding of NOS, claiming that "studying students' views about the nature of science is best done in a context where it is possible to talk about particular theories or particular pieces of evidence" (p. 355). Their study of a large-enrollment course for nonmajors showed that favorable improvements in students' understanding of NOS are possible in such courses. Our study makes a further contribution by examining laboratory-based science courses as a context for teaching and learning about NOS, with specific regard to preservice teachers.

Our work adopted a constructivist approach, in which learners' experiences are believed to affect their cognitive structures and scientific knowledge is constructed when individuals engage socially in discussions about shared problems or tasks.

Method

The Research Approach and the Study Context

The design of the study was qualitative and exploratory in nature (LeCompte and Priessle 1993; Marshall and Rossman 2006), which highlights the importance of contexts, settings, and in-depth understandings of participants' perspectives. The present study focused on the meanings that PSTs attributed to the NOS aspects.

This study was carried out during the Laboratory Application in Science II course, which is offered in spring semester for third year PSTs. This course was coordinated by the first author of this study and taught by two other doctoral teaching assistants. The course was redesigned and extended to provide meaningful and practical experiences in science and to help PSTs' gain deeper understanding of NOS. The new design promoted PSTs' active involvement in scientific activities and discussions. Table 1 provides an overview of the organization of a typical laboratory activity implemented as a class session.

In this study, the researchers developed and/or adapted inquiry-based laboratory activities related to focus on the aspects of NOS for each week. We relied on existing activities for teaching NOS, including black box activities, activities related to fossils, and evolution activities (Bell

Table 1 Organization of weekly course activities

Week	Time	Content
1	15–20 min	Quiz, related to laboratory activities and the aspect of NOS
	2 h	Laboratory activities related to the aspect of NOS
	1 h	Presentation and discussion about the results of activities and relationship to the NOS aspect
	30 min	Reflection paper, related to laboratory activities and the aspect of NOS

2008; National Academy of Sciences [NAS] 1998). On the other hand, while developing new inquiry-based laboratory activities, the researchers utilized science contexts such as photosynthesis, germination, gases, electrolysis, evolution, and buoyancy. To ensure the appropriateness of each of the laboratory activities developed for this study and their fit with explicit approaches of teaching NOS, the researchers also sought expert opinions. Table 2 provides an overview of the nature of seven NOS aspects addressed each week and names of activities.

During the semester, the instructors focused on only one aspect of NOS in each week and PSTs did an inquiry-based activity related to only one aspect of NOS for each week. While

Table 2 Aspects of the NOS and corresponding laboratory activities

Week	NOS aspect	Laboratory activity
1–2	The empirical nature of scientific knowledge	Germination of a seed (developed by the researcher, 2008); this activity was a science project for 2 weeks, participants tried to find which variables affect the rate of germination
		Photosynthesis (adapted from, Baruch 2008); for this activity, participants formed groups and designed investigations to determine which variables affect photosynthesis
3	Observations, inference, and theoretical entities in science	Black box (adapted from Lederman and Abd-El-Khalick 1998); participants observed a black box into which an amount of water was poured and double that amount exited from the box. Students developed models to represent what they believed was inside of the black box
4	Scientific theories and laws	Boyle–Mariotte and Gravity Laws (develop by the researcher, 2008); every group chose one law and related theory and groups formed different experimental designs based on those
5	The theory-laden nature of scientific knowledge	Evolution theories (adapted from NAS 1998); participants had the same data but two different theories about evolution and they reached different conclusions at the end of the activity
6	The tentative nature of scientific knowledge	Age of fossils (developed by the researcher, 2008); every participant was given some fossil fragments and, according to the given information, participants tried to decide the fragments' ages
7	The creative and imaginative nature of scientific knowledge	Real fossils, real science (adapted from Bell 2008); each group was provided different fossil fragments and was asked to draw what they believed the entire fossil looked like
8	The social and cultural embeddedness of scientific knowledge	Which water (developed by the researcher, 2008); participants were asked to role play groups in society with different needs. Each group then set up an investigation to explore different properties of water related to their needs

conducting this study, each week, PSTs were given a laboratory manual prior to class. Each laboratory manual started with a reading text about the aspect of NOS that is the focus of that week. The reading text introduced PSTs to the particular aspect of NOS prior to each laboratory activity, providing them with a conceptual framework for interpreting scientific investigations. Before conducting the inquiry-based laboratory activity, every week, PSTs took a pre-quiz that included two or three questions related to the activities and the aspect of NOS. Therefore, this part had an important role for initiating explicit NOS teaching. During each activity, PSTs completed a given task by using their SPS. Given tasks were generally related to stating group purpose, stating group hypothesis, defining manipulated and controlled variables, and setting up experimental design. Even though PSTs worked as a group, they completed their laboratory reports individually. While completing the sheets, PSTs asked questions and discussed their tasks with each other. Furthermore, at the end of the instructor's presentation, all groups shared and discussed their results with other groups in the laboratory class. Thus, PSTs joined small-group and whole-class discussions each week.

At the end of each inquiry-based laboratory activity, the presentation and discussion about the results of activities and their relationships with the NOS aspect took an hour. At the beginning of this part, there was a PowerPoint presentation to reflect science educators' and the researchers' NOS views (e.g., Lederman et al. 2002; Schwartz et al. 2004a, b). Explicit teaching of NOS aspects were also addressed in this part. This explicit presentation was followed by PSTs' reflective discussions of the target seven NOS aspects. The researcher explained the NOS aspect and managed the discussion among groups every week.

Participants

A total of 52 PSTs enrolled in the Laboratory Application in Science II; at the beginning of the course, 45 out of 52 PSTs agreed to voluntarily participate in the study. Of the 45 PSTs, 34 were female and 11 were male, with a mean age of 22.8 years (ranging from 21 to 29 years). During the spring semester, this course was offered in two different sections. The first section contained 27 PSTs and the second section contained 25 PSTs; both sections met 4 h/week. At the beginning of the semester, PSTs selected their own section and formed their study group (six groups per section, each group included generally four to five PSTs). All of the PSTs were juniors and had the same science major background. The PSTs completed science coursework in biology, chemistry, physics, and mathematics during their first 2 years of teacher education program.

Data Collection

VNOS-B Questionnaire

The Views of Nature of Science Questionnaire Version B (VNOS-B) includes seven items related to science teachers' views of the tentative, empirical, creative, theory-laden, and social–cultural aspects and also the function of and relationship between theories and laws and the distinction between observations and inferences (Lederman et al. 2002). After the development of this questionnaire, the researchers investigated the construct validity of the VNOS-B. According to this study, the VNOS-B effectively differentiates between experts' and novices' views of NOS (Lederman et al. 2002). The questionnaire was first administered at the beginning of the semester to determine PSTs' NOS views and was applied again at the end of the semester to determine the changes in PSTs' NOS views.

Data Analysis and Reliability of the Coding

All of the data were analyzed at the end of the course because the researchers tried to avoid some prejudgments, which would affect the study. The PSTs' responses to the VNOS-B were word-processed and entered into the NVivo 8 qualitative data analysis software (QSR International 2008). A three-stage data analysis technique was devised. The unit of analysis was a statement, defined by Palmquist and Finley as "a paragraph, group of sentences, sentence or phrase that contained a single unambiguous theme about the nature of science" (1997, p. 600). During the first stage of data analysis, the first author assigned codes relevant to the aspect of NOS addressed in PSTs' statements (such as empirical, creative, and subjective). In the second stage of the analysis, all statements assigned to a particular code (e.g., creative) were reviewed and coded in further detail to capture PSTs' views considering that aspect (e.g., designing experiments involves the use of creativity). In the third stage of the analysis, all statements were categorized to find out whether they matched the contemporary views of science (as described in the literature review and reforms) or traditional "myths" or "misconceptions" about science or if they were a mix of contemporary and traditional views. Consequently, in this study, all of the statements about NOS views were classified as inconsistent, transitional, and consistent with current reforms. At the beginning of the coding process, a start code was utilized, but the start code was dynamic, not static. When new themes and ideas emerged, they were added or primary codes were modified. All of the statements were coded according to Lederman et al. (2002) and Hanuscin (2009, Unpublished manuscripts). According to Lederman et al. (2002), inconsistent coding statements are naïve views. As for the transitional coding statements, they include some but not all informed views. However, consistent coding statements are suitable views according to recent reforms.

All of the processes, including analyzing data, defining statements, deciding themes, and assigning codes, were validated through extensive discussions with three of the researchers. Upon developing and assigning codes, the researchers had a detailed discussion about codes. New codes were created accordingly and were categorized in such a way to highlight the strengths and weaknesses of the activities designed for use in the course.

Results

Each of the NOS aspects was investigated in depth according to PSTs' statements for pre- and post-VNOS-B results. According to the VNOS-B results, 37 PSTs joined the pre-application and 41 PSTs attended the post-application. Therefore, comparisons were constructed between pre- and post-application results for these PSTs. Table 3 presents all the observed categories for each NOS aspect for pre- and post-VNOS-B. In Table 3, the numbers refer to the total PSTs, who responded to the specific categories and the percentages refer to the rates for all PSTs.

Empirical Basis of NOS

Five categories were constructed under the empirical basis of the NOS aspect. According to the posttest results, for four categories, the numbers of consistent responses increased regarding the pre- to post-application of the VNOS-B. The post responses for the categories that scientific knowledge is empirically based, observation is important for scientific knowledge, and scientists' opinions are subjective showed developments about empirical NOS

Table 3 Prevalent views about NOS from pre- and post-VNOS-B

NOS tenets and observed categories	Pre-VNOS-B, out of 37 (%)	Post-VNOS-B, out of 41 (%)
Empirical basis of NOS		
Scientific knowledge is empirical-based	28 (75, 67)	35 (85, 36)
Scientific knowledge requires empirical evidence	15 (40, 54)	14 (34, 24)
Observation is important for scientific knowledge	3 (8, 10)	5 (12, 19)
Scientists' opinions are subjective	28 (75, 67)	37 (90, 34)
Scientific knowledge is objective	8 (21, 62)	2 (4, 87)
Observation and inference		
Observation for experimental evidence	2 (5, 40)	5 (12, 19)
Inference for models in science	8 (21, 62)	17 (41, 46)
Observation and inference are different	4 (10, 81)	8 (19, 51)
Scientific knowledge is inferred	21 (56, 75)	28 (68, 29)
Scientific knowledge is observed	15 (40, 54)	10 (24, 39)
Theory and law		
Theories do not become laws	0 (0)	12 (29, 36)
Theories explain laws	4 (10, 81)	31 (75, 60)
Laws cannot change	27 (72, 97)	5 (12, 19)
Theories can change	18 (48, 64)	38 (92, 68)
Subjectivity of scientific knowledge		
Creativity and imagination cause subjectivity	2 (5, 40)	9 (21, 95)
Educational background causes subjectivity	5 (13, 52)	16 (39)
Personal references cause subjectivity	30 (81)	34 (82, 92)
Using existing theories causes subjectivity	6 (16, 21)	21 (51, 21)
Tentativeness of scientific knowledge		
Technology and new evidence can change knowledge	7 (18, 91)	21 (51, 21)
Tentativeness promotes scientific development	3 (8, 10)	17 (41, 46)
Truth of scientific knowledge	11 (29, 72)	2 (4, 87)
Creativity and imagination		
Science and art are different	29 (78, 37)	20 (48, 78)
Science and art are similar	20 (54)	36 (87, 80)
Scientists do not use creativity and imagination	5 (13, 52)	0 (0)
Scientists partially use creativity and imagination	10 (27)	5 (12, 19)
Scientists use creativity and imagination	20 (54)	38 (92, 60)
Sociocultural effects		
Sociocultural factors affect scientific knowledge	5 (13, 52)	17 (41, 46)

aspects. In addition, for the category named as "scientific knowledge is objective," PSTs' views were accepted as not informed because of decreasing pattern in percentages. There is an example, which represents this subcategory; part #14 from pre-VNOS-B: In science, absolute and unchangeable findings can be reached.

A total of 8 (21, 62 %) participants declared similar statements about the objectivity of scientific knowledge; however, this number decreased to 2 (4, 87 %) at the posttest. As an example, PST #38 from post-VNOS-B: Scientific knowledge is more objective.

Observation and Inference

According to Table 3, the PSTs developed an understanding of all of the subcategories about observation and inference. Post-VNOS-B results showed that the PSTs' numbers and percentages were increased with respect to their pre-application for the first four categories. The last category, "scientific knowledge is observed," did not provide informed views about observation and inference. A total of 15 (40, 54 %) PSTs mentioned about observing as part of scientific knowledge, which were related to the structure of the atom. There were decreases in the numbers of participants and percentages according to their pretest results.

Theory and Law

Table 3 illustrates changes in PSTs' views about theory and law; for all of the subcategories, PSTs developed an understanding of this aspect according to their pre-application results.

According to post-VNOS-B results, some PSTs stated that there is no hierarchical relationship between theories and laws and that they are different kinds of scientific knowledge. Although, there is nobody mentioned at pre-application, a total of 12 (29, 36 %) PSTs gave statements at post-application. There is a quotation, which represents this subcategory; PST #31 from post-VNOS-B: Theory and law are different and they do not become one.

In addition, this table showed that the PSTs' numbers and percentages were decreased with respect to their pre-application for one subcategory: Laws cannot change. While the numbers and percentages of participants were 27 (72, 97 %) in the pretest, at the end of the course, these decreased to 5 (12, 19 %). For example, PST #10 from pre-VNOS-B: … while whether or not the evolution theory is true is still being discussed, Newton's laws cannot be changed. That is, a law cannot be changed.

As a conclusion, during the activity in the laboratory, PSTs studied a law (a phenomenon) and some theories to explain this phenomenon. At the end, they recognized that theories and laws are different types of scientific knowledge and one does not develop into the other.

Subjectivity of Scientific Knowledge

In order to detect the effectiveness of intervention about the subjectivity of scientific knowledge, Table 3 showed that PSTs realized the importance of all of the subcategories of the NOS aspect. The most striking change in subcategories was detected as using existing theories. According to their pretest result, only 6 (16, 21 %) PSTs mentioned about using existing theories. However, after the intervention, 21 (51, 21 %) PSTs focused on the importance of existing theories for the subjectivity of scientific knowledge. For example, PST #8 from post-VNOS-B: Scientists can follow different theories, thus they can claim different opinions and they can make different conclusions.

Table 3 shows that PSTs' developed other categories related to subjectivity, that creativity–imagination, educational background, and personal references cause subjectivity.

Tentativeness of Scientific Knowledge

Tentativeness is one of the most important characteristics of scientific knowledge. Table 3 includes three subcategories about tentativeness. While the numbers and percentages of PSTs were 7 (18, 91 %) in the pretest, at the end of the course, these increased to 21 (51, 21 %) for "Technology and new evidence can change scientific knowledge." For example, PST #15 from post-VNOS-B: Scientific knowledge is tentative. If we have new evidence, scientific knowledge can be changed.

Similarly, PSTs realized that the characteristic of tentativeness promotes the development of scientific knowledge. Only 3 (8, 10 %) PSTs mentioned this subcategory at the pretest; however, 17 (41, 46 %) PSTs mentioned this subcategory at the posttest. These numbers and percentages show developments in understanding the tentativeness of the NOS. For example, PST #4 from post-VNOS-B: Theories can change, science should be developed by these changes.

Creativity and Imagination

In order to show changes in the PSTs' understanding of creativity–imagination and its subcategories, Table 3 demonstrates that, for all of the subcategories, participants developed their understanding of this aspect, according to their pre-VNOS-B results. PSTs have made the most important developments for three subcategories, which are accepted as misconceptions. Firstly, while the numbers and percentages of PSTs were 29 (78, 37 %) in the pretest, at the end of the course, these decreased to 20 (48, 78 %) for "Science and art are different." There is a quotation, which represents this subcategory; PST #12 from pre-VNOS-B: Science reaches its goals by experiments, observations, and research. Art is a human product; it is completely related to thinking, creativity, and imagination.

Second, 5 (13, 52 %) PSTs stated, "Scientists do not use creativity and imagination" in the pretest; however, in the posttest, nobody mentioned about this subcategory. For example, PST #32 from pre-VNOS-B: Scientists should not use their imagination because science is not a branch to show the creativity of humans, it should be objective.

Third, while 10 (27 %) participants gave statements about "Scientists partially use creativity and imagination," these numbers decreased to 5 (12, 19 %) after the intervention. For example, PST #20 from pre-VNOS-B: Scientists cannot use their creativity during planning and designing, but after data collection, they can use their creativity.

Furthermore, at the end of the intervention, more PSTs showed adequate understanding that scientists use their creativity and imagination. For the subcategories, the numbers and percentages increased from 20 (54 %) to 38 (92, 60 %) according to the post-VNOS-B results. For example, PST #21 from post-VNOS-B: Scientists use creativity and imagination during all of their work, when they are interpreting data and setting the experimental design, they use creativity.

Sociocultural Effect

According to the pre- and post-VNOS-B results, PSTs develop their understanding of the sociocultural effects of science. According to Table 3, the numbers and percentages of PSTs increased from 5 (13, 52 %) to 17 (41, 46 %). For example, PST #34 from post-VNOS-B: Scientists can be affected by their culture, beliefs, backgrounds, needs, and previous theories. Moreover, the VNOS-B questionnaire does not include any direct questions for sociocultural effect.

Changes in Individual Participants' Views of NOS

Individual PSTs' developments in terms of understanding the NOS aspects were investigated using their answers for the pre- and post-VNOS-B questionnaire. The pretest was applied at the beginning of the intervention and the posttest was applied at the end of the semester. The

PSTs' answers were assigned as inconsistent, transitional, and consistent according to science education reforms. In order to show changes, Table 4 was constructed for each aspect of the NOS. The table represents 34 PSTs' statements because 11 PSTs (7 pre; 4 post) did not complete the VNOS-B in the laboratory. Therefore, these PSTs' pre and post VNOS-B results could not be compared.

From Table 4, it can be concluded that many PSTs have developed the levels of their understanding of each aspect of the NOS. However, especially for two aspects, which are the empirical basis and sociocultural effect, PSTs generally resisted to change their previous views.

Table 4 shows that no development was found for some of the PSTs (18 out of 34) regarding the empirical basis of their NOS views. Some of the PSTs (13) have transitional views, and 5 have inconsistent views with the current reforms. These PSTs did not change their conceptual understanding during the laboratory activities because they were familiar with the acquisition of scientific knowledge by means of experiments from their educational life. This situation can be explained by the lack of the first condition of the conceptual change model. According to the model (Posner et al. 1982), if learners meet a new situation, it causes a condition of dissatisfaction. However, some of the PSTs were not confronted with a new situation. Clough (2006) applied Appleton's (1993) constructivist model of learning in science to consider learners' responses to the demands of conceptual change with specific regard to understanding NOS. This model emphasizes that learners would ideally exit from

Table 4 Changes in PSTs' views of the aspect of NOS

NOS aspects			Post-VNOS-B		
			Inconsistent	Transitional	Consistent
1.Empirical basis of NOS	Pre-VNOS-B	Inconsistent	5	9	0
		Transitional	1	13	5
		Consistent	0	0	1
2. Observation and inference	Pre-VNOS-B	Inconsistent	2	22	3
		Transitional	1	3	3
		Consistent	0	0	0
3. Theory and law	Pre-VNOS-B	Inconsistent	1	22	10
		Transitional	0	1	0
		Consistent	0	0	0
4. Subjectivity	Pre-VNOS-B	Inconsistent	1	13	8
		Transitional	0	5	7
		Consistent	0	0	0
5. Tentativeness	Pre-VNOS-B	Inconsistent	3	22	1
		Transitional	0	5	3
		Consistent	0	0	0
6. Creativity and imagination	Pre-VNOS-B	Inconsistent	0	3	7
		Transitional	0	4	15
		Consistent	0	0	5
7. Sociocultural effect	Pre-VNOS-B	Inconsistent	18	7	6
		Transitional	0	1	2
		Consistent	0	0	0

instruction only after their deep cognitive effort resulted in understandings that are both consistent with their learning experiences and congruent with the accepted scientific knowledge. Learners may exit prematurely from instruction possessing what appears to be an idea that fits with their existing knowledge, but does not conform to scientifically accepted views. When this occurs, “pre-existing NOS ideas have not been abandoned, only slightly modified or left intact with new schema created that are disconnected from the larger conceptual framework” (2006, p. 470). Clough (2006) suggested that students think their ideas match the new situations; therefore, they do not change their previous ideas.

From the table, it can be seen that many (28 out of 34) PSTs developed their NOS views about observation and inference. However, at the end of the semester, six PSTs did not show any development about the importance and difference between observation and inference for generating scientific knowledge.

According to the findings, almost all of the PSTs develop their NOS understanding about theory and law; only two PSTs did not present any consistent view for the view of theory and law. Literature showed that many preservice teachers accepted a hierarchical relation between theory and law and many of them thought that, if there is enough proof, theories might become laws as a high-level scientific knowledge (Abd-El-Khalick et al. 1998; Bell et al. 2000).

Table 4 illustrated that many (28 out of 34) PSTs enhanced their NOS views about the subjectivity of scientific knowledge. Only six PSTs resisted changing their views about subjectivity. Although past studies showed that preservice teachers generally accepted the main idea that scientists should be objective not subjective (Murcia and Schibeci 1999), in this study, PSTs improved their views substantially.

Although some studies showed that some of the preservice teachers have inconsistent views about tentativeness (Murcia and Schibeci 1999), some preservice teachers have gained informed views (Abd-El-Khalick et al. 1998). In this study, after the laboratory instruction, many (26 out of 34) PSTs changed their inconsistent or transitional views to consistent views. Eight PSTs did not present any informed statement after the instruction.

From the table, it can be seen that many (25 out of 34) PSTs indicated consistent views about creativity, similar to some studies (Abd-El-Khalick et al. 1998; Bell et al. 2000; Murcia and Schibeci 1999). Four PSTs did not present any development about their transitional views about creativity and imagination.

In this study, the last NOS aspect is sociocultural effect on scientific knowledge. According to the pre- and post-VNOS-B application, some (15 out of 34) PSTs showed changes in their views. However, many (18 out of 34) PSTs did not present any statement about their consistent views. This situation can be explained by the instrument (VNOS-B); it did not include any question directly related to sociocultural effect on scientific knowledge.

Discussion and Conclusion

At the beginning of the semester, many of the PSTs held NOS views that were described as “inconsistent” with science reforms similar to past studies (Lederman 1992). However, at the end of the study, post data results showed that many of the PSTs improved their understanding for many aspects of NOS. Moreover, at the end of the course, as a group, the PSTs’ number of statements that were aligned with contemporary views of NOS increased for all aspects.

According to the findings, there are developments in PSTs’ understanding of empirical basis and its subcategories (Table 3). PSTs articulated that knowledge in science relies on evidence rather than authority. Moreover, they focused on the fact that scientific knowledge should be reliable, and to support reliability, evidence was needed. These findings are similar to previous studies, which showed that preservice teachers articulated more sufficient views about the empirical NOS (Akerson et al. 2000; Buaraphan 2011; Thye and Kwen 2003). The intervention was begun with the empirical basis of NOS because the researchers thought that PSTs would be most familiar with the idea of evidence versus other aspects such as the sociocultural embeddedness of science. It was expected that some students would hold the idea that evidence could be used to "prove" scientific ideas.

In Turkey, previous studies showed that PSTs held some inconsistent views about the empirical-based aspect of NOS. For instance, "[PSTs] believed that scientific knowledge should be proven true based on objective observation or experimental evidences" (Erdogan et al. 2006, p. 282). Similarly, another study determined this negative condition about the empirical basis of NOS for Turkish PSTs (Liang et al. 2009). However, the present study showed that half (15) of the PSTs develop their views about the empirical NOS aspect at the end of the semester (Table 4). It can be concluded that the explicit–reflective and inquiry-based laboratory instruction had an effect on PSTs, enhancing their understanding about the empirical NOS aspect. Findings indicated that not all PSTs developed views for every aspect of NOS. There are some explanations for this situation. According to the first author's observations, some of the PSTs did not join the discussion parts at the end of the laboratory activities. The other important issue was that constricted time might limit some of the PSTs ability to share their ideas about NOS views.

At the end of the course, PSTs expressed that observations and inferences are different. Both of them are important for generating scientific knowledge. According to the data analyses, this aspect included five subcategories (Table 3). Compared with these subcategories, according to the pre and post results, PSTs elucidated adequate views of these categories at the end of the study. Especially while answering the question from VNOS-B about how the modern atom structure is decided, PSTs enhanced their understanding about the importance of models in science and inferential scientific knowledge. Many PSTs accepted that scientific models reflect the exact phenomena in nature, although they were not aware of their role about representing phenomena and their limitations (Buaraphan 2011; Thye and Kwen 2003). Previous research showed that some teachers naively believed that scientists should make the same inferences and observations from the same phenomena because scientists are objective (McComas 1998). A study revealed that, in the sample, many (31 %) of the Turkish PSTs hold inconsistent views, in which scientists might have different interpretations, but they would make the same observations because observations were facts (Liang et al. 2009). At the end of the present study, approximately 83 % of PSTs showed developments about this NOS aspect. It can be stated that the black box is an effective activity to enhance PSTs' NOS views, while conducting it together with the explicit–reflective instruction in the laboratory.

According to the findings, PSTs developed their understanding about theories and laws. They expressed that theories and laws are different kinds of scientific knowledge and that a theory does not become a law. However, at the beginning, PSTs hold some similar naïve views (e.g., theories become laws after being proven many times) with previous studies about this NOS aspect (Buaraphan 2011). They had some common misconceptions consistent with previous findings, such as there are hierarchical steps among hypothesis, theories, and laws (e.g., Hanuscin et al. 2006; McComas and Olson 1998). Moreover, many PSTs hold another misconception, that is, laws cannot be changed and they are universal. A recent study revealed that, in the sample, many (95 %) of the Turkish PSTs stated that laws are proven by theories (Liang et al. 2009). Another study in Turkey showed that PSTs proposed that laws have a higher status than theories and they did not realize that theories do not become laws (Erdogan et al. 2006). Sandoval and Morrison (2003) studied and reported on high school students' views about theories and theory change as one of the NOS aspects. They focused on the role of inquiry experiences for developing aspects of the NOS. They did not find any development and they emphasized the importance of explicit instruction. The current study applied not only inquiry-based instruction but also explicit–reflective instruction.

Some PSTs mentioned "science teachers" as a source of these misunderstandings. It can be concluded that science teachers have an important role in constructing students' understandings of NOS aspects. In addition, PSTs stated that high school science books include some misconceptions about theories and laws. This result is consistent with previous studies (Yalvac et al. 2007; Irez 2009). The researchers criticized high school textbooks and they found out that there was a unit in some textbooks that included the hierarchical situation among hypothesis, theories, and laws.

The results showed that many PSTs hold inconsistent views about subjectivity at the beginning of the semester. After the course, except for six PSTs, all of them developed their understandings and indicated some reasons as factors for the subjectivity of scientific knowledge (Table 4). PSTs recognized that scientists' creativities and imaginations, educational backgrounds, personal preferences, and use of existing theories can affect scientific studies. In this study, there was a specific activity for subjectivity; it was related to existing theories. After the activity, PSTs understood the effects of existing theories on scientific investigations. Moreover, they concluded that scientists are affected by theories during scientific research, this causes subjectivity in science. Therefore, scientific knowledge is theory-laden. In addition, their perspectives toward science were changed from an objective perspective to a subjective perspective.

Past research showed that some preservice teachers proposed that scientists should be objective and that their research should not be influenced by existing theories (Murcia and Schibeci 1999; Haidar 1999). In their study, Akerson et al. (2000)) concluded that participants completed relatively less substantial gains in understanding subjectivity. During their intervention, the researchers shared a few brief examples from the history of science; thus, they stated that this was not enough to develop the participants' NOS views about subjectivity. In the present study, the PSTs did the inquiry-based laboratory activity; at the end, they discussed and shared their findings. Therefore, PSTs develop consistent views about subjectivity at the end of the explicit–reflective and inquiry-based laboratory instruction.

At the end of the semester, prospective science teachers developed their understandings about the tentativeness of scientific knowledge. PSTs realized a characteristic of scientific knowledge, that is, it is subject to change (Table 4). Some research indicated that preservice teachers were not aware of the importance of tentativeness for the development of science (Murcia and Schibeci 1999). However, in this study, many PSTs expressed that scientific knowledge is not absolute or that science is not a certain knowledge. PSTs stated that the changes were done by means of technological developments and new lines of evidence. This finding is consistent with the results in the literature; many preservice teachers hold informed views about tentative NOS, but the participants proposed that new technology is the only reason for tentativeness (Akerson et al. 2000; Liang et al. 2009). On the other hand, in the current study, the PSTs stated that new interpretations could change existing scientific knowledge, after the activity. Moreover, some PSTs focused on the role of tentativeness to develop scientific knowledge; this is important because PSTs understood the main idea under tentativeness, it promotes scientific development and it is not failure of scientific knowledge. Furthermore, at the end of the semester, PSTs changed their views about the truth of scientific knowledge; they linked this aspect to modern science concepts in school.

According to the findings, PSTs stressed the importance of creativity and imagination for scientific knowledge at the end of the semester (Table 3). In accordance with the literature, PSTs in Turkey hold inconsistent views about this NOS aspect; they expressed that scientists do not use their creativities and imaginations in generating scientific knowledge (Erdogan et al. 2006; Liang et al. 2009). On the other hand, the PSTs in this study emphasized that scientists use their creativities and imaginations during their scientific investigations. A similar finding was found by Abd-El-Khalick et al. (1998); creativity can be used when generating hypotheses, designing research, and interpreting data. Therefore, creativity and imagination affect scientific knowledge.

Moreover, PSTs discussed some possible reasons for the different creativities and imaginations of scientists. For example, culture and religion may affect a scientist's creativity; thus, it can be related to the subjectivity of scientific knowledge (Bell et al. 2000). Although some PSTs stated that scientists do not use creativity and imagination or partially use creativity and imagination at the outset of the semester, they elucidated more views that are adequate after the course. Furthermore, after the specific activity, PSTs perception about "scientists" was changed; they realized that scientists are normal people like others, they are not superman. A similar result was found by Morrison et al. (2009), who conducted a study in an authentic research environment and teachers had a chance to interact with scientists on an informal level. The researchers gave an opportunity for teachers to observe, discuss, and have time to talk about science with scientists. After their study, elementary science teachers stated that "they [scientist] are people just like me" (p. 399); the present study showed a similar result without any interaction between scientists and PSTs. Therefore, it can be concluded that the specific activity had an important effect in developing PSTs' views. These findings showed that a suitable inquiry-based laboratory activity engaged with explicit–reflective discussion could promote more development about the NOS aspect in a limited time.

The results showed that many PSTs realized that social factors affect the development of scientific knowledge. Some research revealed that PSTs in Turkey did not demonstrate informed understanding of the role of social and cultural factors for scientific knowledge (Erdogan et al. 2006; Liang et al. 2009). In Western society, researchers used some historical examples to improve this NOS aspect; however, studies showed that developing this NOS aspect is not straightforward for PSTs (Abd-El-Khalick et al. 1998; Akerson et al. 2000; Tairab 2001).

In the current study, the PSTs demonstrated adequate views for the social and cultural aspects of NOS at the end of the course. They emphasized that society and culture can affect science. They discussed that science is constructed by scientists in society, and they proposed that science and society could not be separate from each other. Some research emphasized similar results; scientific enterprise is affected by society and culture and economic issues can lead research (Haidar 1999; Murcia and Schibeci 1999).

The findings further illustrate that explicit–reflective instruction is effective in the context of inquiry-based laboratory instruction. On the other hand, Khishfe and Abd-El-Khalick (2002) compared an implicit inquiry-oriented approach and an explicit and reflective inquiry-oriented approach, and they concluded the explicit–reflective and inquiry-oriented approach is more effective than the former approach. Moreover, they expressed that "… inquiry by itself seems insufficient to teach students about NOS" (p. 574). As the authors mentioned the inquiry approach does not have any direct role in understanding NOS aspects, the inquiry approach, however, supports learners in constructing their understanding. Therefore, using these approaches with the explicit–reflective method is wise, and it promotes the permanence of understandings. As a result, the inquiry-based laboratory activities were used and they encouraged the development of NOS understanding. In addition, the explicit–reflective teaching provided more opportunities for PSTs to understand contemporary views and change their naïve views.

Implications

Science teachers have an important role in the implementation of curriculum reforms for science classes (Abd-El-Khalick et al. 1998). For this reason, teachers should develop informed views about NOS, and they should translate their understanding into science classes (Lederman 2007). However, according to the literature, science teachers do not have informed views about NOS (Lederman 1992, 2007). For instance, PSTs accepted science as "a process of discovering what is out there, not as a human process of inventing explanations that work" (Abell and Smith 1994, p. 484). Therefore, it is vital that consideration be given to PSTs' conceptual understandings of NOS. While planning some courses, which are related to training preservice teachers, NOS views should be integrated consciously (Akerson et al. 2000). The results of this study propose that this can be accomplished by means of planning the explicit–reflective and inquiry-based laboratory instructions.

According to science education reforms, students should have adequate views about the characteristics of scientific knowledge regardless of cultures (NRC 1996; MoNE 2004). This study was conducted in Turkey. Developing contemporary NOS views has an important part in the newly developed science education curriculum that aims to develop scientifically literate people in Turkey (Liang et al. 2009; MoNE 2004; Yalvac et al. 2007). Science curricula in elementary and high schools in Turkey were content-based before 2001. They included too many science concepts, and teachers had to choose traditional teaching methods to complete all topics during semesters (Simsek and Yildirim 2001). Recent reform movements affected the Turkish education system, and teacher education was redesigned and the new program promoted field experiences, scientific literacy, and contemporary teaching methods (MoNE 2004). After the newly developed science curricula, the central goal of science education as teaching facts and theories changed. In addition, student-centered teaching methods were suggested. However, some national exams constituted a problem in the Turkish education system because students were encouraged to master the science content knowledge. Students were expected to get high scores for high school and university entrance examinations. These exams require more content knowledge (Yalvac et al. 2007). For this reason, it is difficult to attain a central objective about NOS for the recent science education curricula. Therefore, science teachers focused on such subject knowledge as chemistry, physics, biology, math, and Turkish. The other aspects related to NOS, such as science and technology studies and environment education parts, were neglected (Cimer 2004).

Teacher education programs and teacher educators in education faculties have a mission to train science teachers to understand NOS properly and to have the essential skills to implement NOS views into their future science classrooms. In addition, teacher preparation programs should be revised according to the current reform. By doing so, some new courses related to teaching NOS can be developed or the existing ones can be reviewed. Science teacher educators should integrate NOS aspects and their teachings into their courses. Moreover, science teacher educators should give opportunities for prospective science teachers to reflect and practice their learning about NOS. Many science teacher educators used their method courses to improve NOS views. With this, they should be aware of other opportunities to develop students' understandings about NOS. Science teacher training programs were accepted as a last opportunity to change traditional NOS views (Abd-El-Khalick and Lederman 2000). Because science teachers are an indispensable factor to improve students' NOS views, some curses should be provided that include NOS aspects (Irez 2006). This study can be one of the ways to train PSTs for science teacher educators and it gives some examples about laboratory activities for science teachers. The results of this study are consistent with studies that propose that students' NOS views may be context-dependent (Ozgelen et al. 2006; Sandoval and Morrison 2003).

According to Erdogan et al. (2006), PSTs in Turkey did not have an adequate understanding of NOS. The authors stressed the lack of emphasis on NOS in science-related courses in teacher training programs, and they suggested using the explicit–reflective-based approach. In addition, they recommended the development of science content courses and method courses to improve PSTs' understanding of NOS views. The researchers concluded that most of the PSTs complete their teacher education program with some traditional views of NOS, and they requested that ways to facilitate PSTs' understanding of NOS be found (Erdogan et al. 2006). In the present study, the science laboratory course was redesigned and NOS views were addressed during the explicit–reflective instruction.

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