IMPROVING PRESERVICE ELEMENTARY TEACHERS' VIEWS OF THE NATURE OF SCIENCE USING EXPLICIT-REFLECTIVE TEACHING IN A SCIENCE, TECHNOLOGY AND SOCIETY COURSE

Mehmet KÜÇÜK
Artvin Çoruh University
TURKEY.

*Abstract***:** *This study examined twelve preservice elementary teachers' views on the nature of science (NOS). The student teachers participated in a cohort group as they took a science, technology and society course during which the target NOS aspects were taught through an explicit/reflective approach. The main goals were to that (1) improve preservice teachers' understanding of NOS and (2) encourage them to teach NOS in their classrooms. Data were collected through Views of the Nature of Science- form C (VNOS-C) survey and followed semi-structured interviews. Both survey and interviews were administered at the beginning and end of the intervention. It was concluded that preservice teachers hold an inadequate understanding of NOS. However after teaching the NOS in an explicit-reflective way, the majority of them improved their understandings of all the NOS aspects except for relationship and distinction between theories and laws. The main result of the study is that for student teachers to really teach NOS to their students, first of all, they need to have intentions about teaching it. This was achieved in the current study by encouraging and supporting student teachers to develop and implement their own NOS activities in real educational contexts to elementary students.*

Introduction

The American National Science Teachers Association (NSTA) explains that the "two major goals of science education are to achieve "scientific literacy for all citizens" and to ensure an adequate supply of scientists, engineers, and science teachers" (NSTA, 1990). There is no one clear definition of "scientific literacy," nevertheless many agree that it is not merely knowing the scientific content knowledge. For someone to be considered scientifically literate, he/she should hold accurate views on the "nature of science" (NOS) including its reliance on inquiry (The American Association for the Advancement of Science (AAAS), 1993; The National Research Council of America (NRC), 1996).

Teaching the NOS to students has long been a goal of science educators (Akerson & Volrich, 2006; Cobern & Loving, 2002; Kang, Scharmann, & Noh, 2005; Lederman, 1992; Moss, Abrams, & Robb, 2001). NOS refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992). These characterizations, nevertheless, remain fairly general, and philosophers of science, historians of science and science educators do not agree on one specific definition of the NOS. However, there is an acceptable level of generality regarding the NOS that is accessible to K-12 students (Lederman & Abd-El-Khalick, 1998; Abd-El-Khalick & Lederman, 2000). The aspects of the scientific enterprise that fall under this level of generality are that scientific knowledge is tentative (subject to change), empirically-based (based on and/or derived from observations of the natural world), subjective (theory-laden), partly the product of human inference, imagination, and creativity (involves the invention of explanation), and socially and culturally embedded. Two additional important aspects as decided by Lederman and Abd-El-Khalick (1998) are (a) the distinction between observations and inferences, and (b) the functions of, and relationships between scientific theories and laws.

The review of research about the NOS presents a detailed summary of individual research investigations. In summary, however, after approximately 50 years of research on the nature of science, the following generalizations can be made (Lederman, 2006):

- K-12 students do not typically possess “adequate” conceptions of NOS.
- K-12 teachers do not typically possess “adequate” conceptions of NOS.
- Conceptions of NOS are best learned through explicit, reflective instruction as opposed to implicitly through experiences with simply “doing” science.
- Teachers' conceptions of NOS are not automatically and necessarily translated into classroom practice.
- Teachers do not regard NOS as an instructional outcome of equal status with that of “traditional” subject matter outcomes.

Early attempts to improve student conceptions of the NOS focused primarily on the development of curricular materials. Included among these materials are Klopfer and Cooley’s (1963) History of Science Cases for High Schools the Physical Science Study Curriculum, and the Biological Sciences Curriculum Study. The impact of these curricula, which tended to address the NOS implicitly through instruction on inquiry and process skills, was mixed (Tamir, 1972; Yager & Wick, 1966). What eventually emerged from this line of curriculum innovation was the realization that teachers play an absolutely critical role in NOS instruction. Subsequent studies focused on assessing preservice and in-service teachers’ understandings of the NOS (Aguirre, Haggerty & Linder, 1990; Gallagher, 1991; Kimball, 1968) and improving teachers’ understandings of the NOS (Billeh & Hasan, 1975; Shapiro, 1996). Those attempts to improve teachers’ understandings of the NOS fall into two generalized categories:

- Implicit approaches, where gains in NOS understandings were assumed to stem implicitly through process skill and/or inquiry based instruction.
- Explicit approaches, where specific aspects of the NOS were addressed purposively and explicitly, often in the context of science history, philosophy, or inquiry-based

instruction.

In general, explicit approaches used in these investigations appeared to be more effective in facilitating desired understandings (Abd-El-Khalick & Lederman, 2000), a conclusion that has been corroborated in several recent investigations (Akerson, Abd-El-Khalick, & Lederman, 2000; Bell, Blair, Crawford, & Lederman, 2003; Khishfe & Abd-El-Khalick, 2002; Moss, Abrams, & Robb, 2001). Furthermore, it is noted that an explicit-reflective approach to enhancing teachers' NOS views was relatively more "effective" than an implicit approach that utilized hands-on or inquiry-oriented science activities lacking explicit references to NOS (Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002). For example a recent study provided evidence in support of using an explicit, reflective-based approach in helping teachers developing more accurate conceptions of the NOS (Dickinson, Abd-El-Khalick, & Lederman, 1999).

Lederman and his research team and colleagues over the past 20 years have focused on the following characteristics of scientific knowledge in their research on NOS (Lederman, 2006).

- Scientific knowledge is, at least partially, based on and/or derived from human imagination and creativity.
- Scientific knowledge necessarily is partially subjective and can never be totally objective.
- Science as a human enterprise is practiced in the context of a larger culture and its practitioners (scientists) are the product of that culture. Science, it follows, affects and is affected by the various elements and intellectual spheres of the culture in which it is embedded.
- Scientific knowledge is never absolute or certain; it is subject to change.
- Scientific knowledge is empirically based.
- The distinction between observation and inference
- The relationship and distinction between scientific laws and theories

Popper (1959) proposed a definition of what counts as scientific: a theory is scientific = theory is falsifiable. This means that a theory exposes itself to test against what we can observe. It can be shown to be false, but not shown to be true. If it passes a test when compared with what we can observe, then it has escaped falsification. Thus, even passing a test is a mark of the scientific. All it means is that a possible falsifying case remained merely possible and did not become actual. In contrast, a theory gets into trouble when a possible falsifying instance becomes actual! If there are enough reliable, actual falsifying instances, then the theory is falsified. From those explanations, it is not possible for a theory to become a law.

It stands to reason that to teach science as inquiry by inquiry, teachers must have "rich and deeply developed understandings of science content, student learning, the "nature of science", and ways to engage students in investigative practices" (Keys & Bryan, 2001, p. 637).

However, research has consistently shown that K-12 students have not attained the desired understandings of NOS (Duschl, 1990; Lederman, 1992). In addition to this science teachers were found to hold several naïve views of NOS (Abd-El-Khalick et al., 1998; Billeh & Hasan, 1975; Bloom, 1989; King, 1991). For example, many teachers believe science is a body of knowledge created by a rigid "scientific method" (Brickhouse, 1990; McComas, 1996), and that students learn best by receiving transmitted knowledge (Keys & Kang, 2000). It is believed that such beliefs are presumed to stem from the teachers' educational experiences in which they have experienced many science classes taught by direct transmission, and have had few opportunities to participate in inquiry activities (NRC, 1999, 2001).

Related to this issue many attempts were undertaken to improve science teachers' conceptions of NOS (Billeh, & Hasan, 1975; Scharmann & Harris, 1992). In a review of these attempts, Abd-El-Khalick and Lederman (1998) concluded that researchers were generally not successful in helping teachers develop understandings that would enable them to "effectively" teach about the NOS. It is still an important issue of that how to teach NOS to student teachers and provide them the impression of how much important to teach it to students. In their school life, students get their first formal science experience in elementary grades. Hence it is important to focus on elementary science teachers' views on the NOS. Teacher education programs could make a change in how prospective teachers view the NOS concepts and learn to teach them when they begin teaching. Thus the current study focused on elementary student teachers similar to many other studies (Akerson, Abd-El-Khalick & Lederman, 2000; Barufaldi, Bethel & Lamb, 1977; Bianchini & Colburn, 2000; Meichtry, 1995).

International literature already has a lot of studies on the assessment of preservice elementary teachers' NOS views and importance of teaching the NOS to them by using an explicit-reflective teaching approach. Examination of the NOS views of the other students from different cultures such as Turkish students, and also if there is a similar effect of an explicit-reflective teaching approach on they are required to be studied. I think that culture has an important effect on the views of people about science, technology and society as also about the NOS views. There are also some research about Turkish student teachers' and high school students' views about the NOS (Çelik, 2003; Gücüm, 2000; Gürses, Doğar & Yalçın, 2005; Kılıç et al., 2005; Macaroğlu, Taşar & Çataloğlu, 1998; Oyman, 2002;Yakmacı, 1998). In those studies it is concluded that student teachers' and high school students' NOS views are not convenient with the modern views. For example, most of the student teachers believe that science is objective, scientific knowledge is tentative, and there is a hierarchical relation between scientific knowledge kinds. However, there is not any study about teaching NOS neither for student teachers nor high school students by using an explicit-reflective approach. Thus, it is an important need to examine elementary student teachers' NOS views and its development by using an explicit- reflective teaching approach to NOS.

International literature has many studies of teaching the NOS for preservice elementary teachers. The current study is different from those because it includes not just teaching NOS to student teachers by using an explicit-reflective approach but also supporting them to develop NOS materials and implement them in real educational contexts for the main duty of the study. In the development process of the NOS materials student teachers were free to choose which aspects of the NOS they wished to include. This freedom served to expose rich data about how Turkish preservice elementary teachers think which of the NOS aspects are more suitable to teach for elementary students.

The purpose of the present study was to assess the influence of a set of activities developed by Lederman and Abd-El-Khalick (1998), and implemented within an explicit, reflective approach, on Turkish preservice elementary teachers' conceptions of NOS. The specific questions that guided this research were: (a) what meanings do Turkish preservice elementary teachers ascribe to some aspects of NOS? And (b) what is the influence, if any, of using a reflective, explicit, activity based approach with preservice teachers' views of these aspects of NOS?

Typically, NOS refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992). There is not a common and shared wisdom about NOS among philosophers, historians, sociologists, and science educators. However, it would be difficult to reject the theory-laden nature of scientific investigations or to defend a deterministic/absolute or empiricist conception of NOS in the 1990s. Moreover, at such a level of generality, some important aspects of NOS are virtually non-controversial (Akerson, Abd-El-Khalick, & Lederman, 2000). Such NOS aspects have been advanced in the recent reform documents in science education, such as Science for All Americans (AAAS, 1990) and National Science Education Standards of America (NRC, 1996).

In the present study I focused on the meanings of Turkish preservice elementary teachers ascribed to the emphasized NOS aspects. Those aspects which I believe are accessible to preservice student teachers and relevant to their lives were adopted and emphasized. These aspects are that scientific knowledge is tentative (subject to change), empirically based (based on and/or derived from observations of the natural world), subjective (theory-laden), partly the product of human inference, imagination, and creativity (involves the invention of explanation), and socially and culturally embedded. Two additional important aspects are the distinction between observation and inferences, and the functions of and relationships between scientific theories and laws.

Methodology

The present study was interpretive in nature (Strauss & Corbin, 1990) and focuses on the meanings that participants ascribed to the emphasized NOS aspects. The data collection was continuous and spanned nearly a three months period in which participants were enrolled in the investigated Science-Technology and Society (STS) course between 2006-2007 academic years.

Participants

I investigated one cohort of Turkish preservice elementary teachers. 12 undergraduate students (10 male and 2 female Turkish fellow citizens) were enrolled in the two sections of a STS course during the fall 2006 semester. The undergraduates' ages ranged between 21 and 24 years, with a median of 22.5 years. These undergraduate students were seeking a bachelor's degree in elementary education to become a classroom teacher. The cohort was in their fifth semesters of their teacher development program which is eight semesters of all. Undergraduate students have taken only three science courses - these are; General Biology, General Chemistry and General Physics -within their teacher development program and only three science courses were required for the teacher education degree.

Context of the Study: Science, Technology and Society Course

I taught the STS course which was a two credit/hours optional course. The classes were held weekly in two-hour blocks throughout the two-month period. The course aimed at helping preservice elementary teachers develop (a) a theoretical framework about science, technology, and society (b) favorable attitudes toward science and science teaching, and (c) deeper understandings of some science content areas such as atom, universe, human beings and genetic, changing world, ecosystem, climate, illness and health. The first five units of this course are "history of science", "science", "scientific literacy", "technology and technology literacy" and "science-technology-society" in sequence. The current investigation took place during the first five units of the STS course.

Intervention

In the content of the STS course, preservice teachers were provided with some activities that were specifically designed to confront faulty understandings of some aspects of NOS. Those activities were taken from literature (Lederman, & Abd-El-Khalick, 1998). These faulty understandings are; scientific knowledge is absolute, objective, not embedded socially and culturally and there is a hierarchical structure between scientific theories and laws. Eight NOS activities were implemented in the first part of the STS course. These were; the *cubes, tricky tracks, the aging teacher, lets find it, young? or old?, the tube, hypothesis boxes, water generator.* These activities were explicitly addressed the six target aspects of NOS except for the functions and relationships of scientific theories and laws. However the last aspect, if there is a relationship between a scientific theory and law was also explicitly explained to student teachers within the tube and hypothesis boxes activities by making a relationship with some scientific theories and laws for example evolution theory and conservation of mass laws. A detailed description of these activities can be found elsewhere (Lederman & Abd-El-Khalick, 1998). However some small-scale arrangements were done in the structures of those activities. For example the name of "the aging president" was changed to "the aging teacher" because of students are expected to show much more interest to teachers' change in time and an aging president is not an appropriate/usual model to the Turkish culture. In the "lets find it" activity a text was used which was about airbag technology in cars. This activity was also developed by using "That's part of life!" activity in the literature (Lederman & Abd-El-Khalick, 1998). Water generator activity was also used (its original form is in Evolution and the Nature of Science Institutes (ENSI) web page).

The Tricky tracks activity addressed the differences between the observation and the inference, and the empirical, creative, imaginative, and tentative nature of scientific knowledge. Three other activities ("The aging teacher," "Lets find it!" and "Young? or Old?") targeted the theory-ladenness and the social and cultural embeddedness of science. Finally, two black-box activities ("The tube" and "The cubes") were used to reinforce participants' understandings of the abovementioned NOS aspects. The activities were purposefully selected to be generic in nature (not content-specific) given the Turkish preservice teachers' limited science content backgrounds.

Each activity was followed by a whole-class discussion that aimed to explicitly highlight the target aspects of the NOS and involve students in active discourse concerning the presented ideas. In these discussions the instructor purposefully supported students to make linkages between the activities implemented and scientists' real experiences toward developing scientific knowledge. One of them - *hypothesis boxes* - has "black-box" variety. In such activities, students were shown a particular phenomenon and asked to infer how it works. Students were then asked to design and construct models that explain the behavior of the original phenomenon without ever "seeing" what was inside the boxes. Ensuing discussions focused on the distinction between observations and inferences, the role of models and theoretical constructs in science, the tentative nature of scientific knowledge, and the role of creativity in devising scientific explanations. This initial activity-based explicit NOS instruction was intended to provide participants with a NOS framework by introducing and sensitizing them to the target NOS aspects. This first phase of the study was completed for two months.

For the second section of the course which was completed for one month, each participant was asked to develop an activity which would be used in teaching one or more aspects of NOS to elementary students. That is to say student teachers developed them and implemented them in real educational contexts with real students. This task was aimed at helping participants articulate and elaborate their acquired NOS understandings, and apply them in various-real educational contexts and also constitute an impression of that teaching the NOS is both fun and interesting if they show an effort to achieve it. For this activity student teachers are asked for developing their activities to teach one or more than one of the NOS aspects to elementary students. These activities were developed individually, and presented to class. In these presentations, they purposefully encouraged to discuss how practical to implement these activities in real elementary classes. Then they were also encouraged to implement them in real learning environments and assess how investigated elementary students learned the examined NOS concepts. These activities were implemented by the subjects and then their results were presented as a research report to the researchers. Participants were also encouraged sharing their project results and feelings about teaching the NOS to real students with their peers in the last section of the STS course. These research reports were critically analyzed and were taken into consideration as the signifiers of student teachers' understandings of and experiences toward teaching the NOS.

Data Collection Methods

An open-ended questionnaire in conjunction with semi-structured interviews was used to assess participants' views of the target aspects of NOS. All participants were administered the questionnaire before and at the conclusion of the course. In addition all participants were also selected for interviewing.

The use of an open-ended questionnaire was intended to avoid the problems inherent in the use of standardized forced-choice paper and pencil NOS assessment instrument. These instruments are based on the problematic assumption that the meanings that respondents ascribe to an instrument items, and the reason s behind their choosing certain responses correspond to those of the instrument developers and/or researchers. Moreover, because they were of the forced-choice type, these instruments often end up imposing a certain view of NOS on respondent (Lederman, Wade, & Bell, 1998). In contrast, open-ended items allow respondents to elucidate their own views regarding the target aspects of NOS and the reasons that underlie their views (Lederman, 1992; Lederman & O'malley, 1990). The ten-item open-ended questionnaire used in the present study was previously used and validated by Lederman et al, (2002).

The main research question that guided the investigations was "What is the influence of an explicit teaching approach on preservice elementary teachers' views on the NOS?" This investigation was qualitative in nature. The data was collected within three months in which the study was conducted. The data were collected using an open-ended questionnaire, *Views of the Nature of Science- Form C (VNOS-C)* (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). This questionnaire was used to assess participants' views of the NOS prior to and at the end of the STS course. The questionnaire consisted of ten open-ended items that assessed participants' views of the tentative, empirical, creative, and subjective nature of science; the role of social and cultural contexts in science; observation versus inference; and the functions and relationships of theories and laws. The researcher, who was also responsible for the implementation phase of the teaching activities, also conducted semi-structured interviews with all students enrolled in the course prior to and at the conclusion of the study. Interview findings were used to explore the validity of participants' responses to the questionnaire items. The participants were provided with their pre/post instruction questionnaires during these interviews and asked to explain and elaborate on their responses. This method was used in several studies to assess subjects' views related to NOS (Akerson, Abd-El-Khalick, & Lederman, 2000; Akerson, Morrison, & McDuffie, 2006; Matkins, Bell, Irwing, & McNall, 2002). The interviews also aimed to generate in-depth profiles of participants' NOS views. The interviews all lasted about 40 minutes and were audio-taped and transcribed for analysis.

Analysis

The researcher and one of colleague analyzed the pre/post-instruction questionnaires and the interviews data. This approach was undertaken because the researcher was also the instructor of the STS course. Thus he might have perceived such data to be partially evaluative of the instructor's performance. The NOS questionnaires and corresponding interview transcripts of the all participants were analyzed and compared to validate participants' responses to the NOS questionnaire items. Next, all NOS questionnaires were analyzed to generate pre-instruction and post-instruction profiles of participants' views of the NOS in the course. Data from each questionnaire was used to generate a summary of the participant's views of NOS related to the target NOS aspects. This process was repeated for all questionnaires. I categorized student responses and conceptions as ''adequate'' if their responses indicated they had a view in line with the accepted NOS position statement. If a participant responded that *"scientific theories change because there might be new evidence collected"* or *"theories change because of new* *evidence or reinterpretation of old evidence"* the response was coded as informed view of tentative nature of scientific theories. If the participant responded that "theories will never change" then the response was coded as "inadequate view of tentative nature of scientific theories". These initial rounds of analysis were followed as we searched the generated summaries for patterns or categories, such as the numbers of students with adequate or informed understandings of target aspects. The generated categories were checked against confirmatory or otherwise contradictory evidence in the data and were modified accordingly. In this process both researchers worked together. Thus I conducted several rounds of category generation, confirmation, and modification to satisfactorily reduce and organize the data. Finally, I compared pre-post profiles to assess changes in participants' NOS views.

For the second part of the study, student teachers' NOS materials were analyzed critically. Their NOS materials were introduced via their names, NOS aspects included and some direct quotes were included from their research reports about their views on how the materials would be effective and their intentions about teaching NOS in their subsequent teaching life were presented in a Table. The research report section which is on student teachers' thoughts on how they could be sure if elementary students learned the aspects of NOS stressed and especially teaching NOS to elementary students is very important. This data source was used as the real signs of preservice elementary teachers' learning of NOS. Thus some direct quotations were taken to enrich the data and discussion.

Results

This section elucidates participant student teachers' pre-instruction and post-instruction views on the targeted aspects of NOS. The number following a students' response refers to an individual participant. Table 1 presents a summary of results from the study. The table shows the percentage of students who held adequate views of NOS with "+" and inadequate view with "–"signs before and after instruction for each of the elements emphasized in the STS course.

Pre– Post–Instruction NOS Views

The result of this study shows that participants' views included several misconceptions about the NOS prior to instruction. None of the students held adequate views of all elements emphasized in the course, though several did hold adequate views of certain conceptions. Table 1 shows that there was a substantial increase in participants who held adequate views of the target aspects of the NOS at the end of the study. There were observed changes in each aspect of the NOS targeted. However, the observed changes were not consistent across the investigated NOS aspects. For example, changes in participants' views were particularly pronounced with regard to the tentative NOS, the distinction between observation and inference, and the social and cultural NOS. Less pronounced changes in participants' views of science were empirical and subjective (theory-laden), and the relationship between theory and law. Table 1 shows student teachers whose NOS views were adequate at the beginning and at the end of the study.

	Observation vs. Inference	Theories & Laws	Empirical Tentative	Creative & Imaginative	Subjective (Theory-Laden) Social & Cultural					
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
ST_1	-	-	-	-	-	-	-	-	-	+
ST_2	-	+	-	-	-	+	-	+	-	+
ST_3	+	+	-	-	-	+	-	+	-	+
ST_4	-	+	-	-	-	+	+	+	-	+
ST_5	-	+	-	-	-	+	+	+	+	+
ST_6	-	-	-	+	-	-	-	+	-	-
ST_7	-	-	-	-	-	+	-	+	-	+
ST_8	-	+	-	+	-	+	-	+	-	+
ST_9	-	+	-	+	-	+	-	+	+	+
ST_{10}	-	+	-	+	-	+	-	+	-	+
ST_{11}	+	+	-	-	-	+	-	+	-	+
ST_{12}	-	-	-	+	-	+	-	+	-	+
	16%	66%	0%	41%	0%	83%	16%	91%	16%	%91

Table 1: Percentage of Participants with "Adequate" Views of the Emphasized Aspects of NOS

The change of participants' pre and post-instruction views were exposed by taking direct quotes from their questionnaires and interviews at the beginning and at the end of the study. If there is any progress in the NOS aspects of the student teachers, it was examined in depth. Both empirical and tentative, and subjective (theory-laden) and social and cultural aspects of the NOS were also combined in these analysis. This is because while the participants answered the questions related to the dinosaurs and atom model which were used as their real views about the empirical and tentative NOS, they usually answered as *"scientists always need scientific data to develop a scientific knowledge, nevertheless this knowledge is not certain*" at the end of the study. This does not mean that no subject was said that science is tentative at the beginning of the study, however they could not explained exactly why this is so, and this was scored as they did not know whether science was tentative or not.

Observation versus Inference

In response to the question "how certain are scientists about the structure of the atom and the evidence scientists used to derive this structure," only 16% of the students reported adequate views on the difference between observation and inference. Most students believed some scientists have conducted some experiments and according to the experimental results they believed that an atom looks like exactly as the model itself. However, two students explained that scientists had conducted experiments and based on the interpretations of the clues they found they reached that model:

> ST_3: I think scientist arrived at this conclusion because of their experiments. For example in the gold panel experiment, alpha rays were sent to the panel and a small amount of them came back; some of them reflected back and some others passed

through the broken...

ST_8: The scientists are certain because they have proved this in some experiments. For example they can examine its inner structure using high powered microscopes.

When compared to the participants who held adequate views of the difference between observation and inference prior to the study (16%), 66% of them expressed adequate views at the conclusion of the study. Several students specifically mentioned the “Tricky Tracks!” and especially “Hypothesis Boxes” activities that were demonstrated in class to help students develop better understandings of the inferential NOS.

ST_2: There is no certainty in science; however science is closer to the truth. The structure of an atom was modeled as experimental evidences, observations and inferences. This does not show an atoms’ inner structure as certainly in this way. Thus they did some observations via experiments and inferred that there is a nucleus and circulating electrons around it. However they can not say that there are certainly protons and neutrons in it, because they did not do observations.

ST_3: Scientists arrived at this model based on some evidences. While determining on this they did many experiments. For example if someone asks us for doing an interpretation about anything, we observe it at first. Looking, touching, testing it we try to gather data like as in the Hypothesis Boxes activities. However scientist did not have a chance to open it look into it directly. Thus their explanations all are inferences according to obtained data…

ST_5: Scientists can not talk absolutely certainly about an atom’s structure because there is not certainty in science. They do some experiments and observe the attitudes of atoms and infer these models moving from different assumptions based on their views.

The Functions of and Relationship between Scientific Theories and Laws

All participants reported inadequate notions about the theories and laws. Many believed in a notion that theories were simply a means to developing laws. Most students believed that with supportive experiments, theories would develop into laws. Thus, the kinds of knowledge explained by theories and laws were not different, just different in terms of the amount of “certainty” that supported each other. This led to the belief that laws were absolute and did not change because they had been “proven” and were the ultimate source of scientific knowledge:

ST_1: The theory is not absolutely proven however laws are proved via many experiments.

ST_5: There is difference between theories and laws. Theories are suspicious truths however laws are accepted certain facts. Thus theories can be destroyed easily; on the other hand, laws can not. Laws are taught students as not destroyed truths.

ST_6: The scientific theory is a knowledge which someone put forward according to

> him/herself and some people accept it is absolutely correct. Scientific law is accepted as correct by everyone and it does not change...

When compared, most participants held a hierarchical view of the relationship between theories and laws at the beginning of the study. However, at the final questionnaires and interviews 41% of the participants adopted the view that scientific theories and laws were different kinds of knowledge and that one did not develop in the other. They all were aware of the difference between the two kinds of knowledge structure; nevertheless they could not describe the meanings of those sufficiently:

> ST_6: These are not the same. A scientific law is accepted by everyone. Its truth is certain just in the conditions of suggested days. However it can change based on the developments of scientific area. A scientific theory is not accepted by everyone and is a product of a scientific research. Its acceptability is lower than laws.

> ST_8: A theory is a kind of knowledge that was based on assumptions, inferences and interpretations. For example related to an atom theory inner structure of it absolutely based on assumptions. Laws are knowledge kinds that are more close to the truth and based on observations, experimental results and experienced and seen facts.

Indeed, participants also seemed to recognize the importance of teaching the difference between theories and laws to help their own students develop an adequate understanding of science:

> ST_3: Theories are the certain knowledge just in the put forward times however its truth is not certain. It does not have any evidence which shows its error. But this does not mean those are not wrong. However theories are accepted until its error was proved. Thus learning theories are not waste time.

> ST_5: We really struggle to learn theories due to the fact that if more people do more tests about natural events current theories would be more valid in the future.

The Empirical and Tentative NOS

No subjects held adequate views of the empirical NOS. None of them recognized exactly that the empirical NOS sets science apart from other disciplines. Most students noted that science includes experiments and these experiments can prove the suggested knowledge to embed its truth. However, none of them used the terms “data”, “proof” or “evidence” in the questionnaires and interviews. They explained that experiments are conducted in science however, not in other disciplines for example in religion, philosophy, etc.

> ST_2: The scientific areas such as physics, biology...etc. are quite different from other research areas. That makes science different is its nature based on experiments and observations. By doing experiments and observations, more realistic knowledge could be exposed. There is not a similar situation in religion and philosophy. There is not a certainty in them. However science reaches to certain

knowledge by doing experiment and research.

ST_5: Science is anyway, experiment for me. That is to say either science is without experiment or it can be grow up. For it is based on experiment, its development is based on experiments.

The majority of the student teachers held also inadequate views of the tentative NOS. They all believed that scientific laws were proven and did not change. Many thought theories did change, but only because they changed into laws, or because of new technologies which allowed us to see things differently.

ST_3: …Theories include a scientist's experiment and observations. Many scientists work on this work and if suggested theory is accepted by other scientists via experiment, this theory becomes a law and does not change.

ST_{11}: Theories of course can change. I really believe it. Many examples from the history supported this idea. While technology develops in time, theories can change and more truths than today are reached…

There were also gains observed in participants' views of the tentative NOS. At the conclusion of the study 83% of the student teachers stated more adequate views of the tentativeness of scientific knowledge. Students most often reported that the reason for a change in a scientific view was due to new evidence, and that creates a better explanation. The participants also expressed a view that all scientific knowledge was subject to change, and could change via a modification of current ideas, or the replacement of current ideas with ones based on better evidence:

ST_2: Scientist' theories can change in time. There is not certainty in science. No body can say that this is certainly true.

ST_3: Scientific knowledge is not certain however it is accepted as true until its contradiction was absolutely embedded.

The Creative and Imaginative NOS

The majority of participants (84%) did not demonstrate adequate understandings of the role of imagination and creativity in generating scientific claims. Most participants did not appreciate the creative work in searching for patterns in data or developing models and theories. For those students who did believe that scientists used creativity they believed more of the role of inventiveness of new items, or making presentations of their results, not of inventing ideas or models and explanations. In addition to those, students who believed that scientist use their creativity and imaginations, could not explained sufficiently in which part of their study and how they use those abilities. They ordinary put forward this idea though without proving and example of it.

ST_1: The scientists use their imaginations because these imaginations orientate scientists for new inventions.

ST_5: If a scientist does not use his /her imaginations and creativity, he/she neither does a quality experiment nor a research. Its reason is that scientists by imagining and using their creativity have great interest about something and concentrated on a theme and do experiments.

In the conclusion of the study, a total of 91% of the participants exited the course with more adequate understandings of the role of creativity and imagination in science. They believed that science, like art, required creativity and imagination. Even though they all explained that scientists use their imaginations and creativity, they believed that scientists mostly use those abilities while suggesting hypothesis than in all the processes of scientific research.

ST_3: Those scientists conclude different results from the same evidences are assign of their imaginations and creativity. Data can not give the exact conclusions. Data's truth analysis achieves this. In those analyses each scientist make an inference based on his/her own experience and arrived at the conclusion. For example scientists examine the same data however tree kinds of hypothesis were appeared. In addition, participants interpreted "creativity" and "imagination" as ways of developing ideas, not just ways of developing new products, as were their statements pre-instruction:

ST_5: The scientist needs creativity and imaginations to put forward quality ideas and models about natural events.

ST_8: The scientist uses their creativity and imaginations both in the planning and organizing data phases and also after gathering data. We are not scientist however while thinking about the hypothesis boxes and its inner structure used out imaginations and creativities…

The Subjective, and Social and Cultural NOS

More than three-fourths (83%) of the participants did not recognize the role that background knowledge and training played in the scientists' development of scientific knowledge. Participants believed scientists were objective to give the best and fairest results in every condition:

ST_3: If something is accepted as science it needs to be objective. However it is impacted from social and political values and lost its objectivity…

ST_4: I think science is universal with it's invents and results. However it can be impacted from its environment. That is to say some one in an environment can not find anything that could not accepted by the society.

The 16% of the student teachers were aware of the social and cultural influences on the interpretation of data. When students were asked to explain a scientific controversy, half of them described the reason of it as being the lack of a full set of data. They dismissed possible influence of background knowledge and cultural background. If they did note an influence of background knowledge, they did relate it to purposeful interpretation of data to support claims they believed should be the correct explanations.

ST_5: I think science reflects cultural values. Because, social and cultural values of everybody are not the same with each others. If they are, the same invents could be found in many places. However for this not the case different invents were found in different places…

ST_{11}: The scientists have different hypothesis and view points. Thus they try some scientific ways based on their hypothesis. Thus they can interpret a case from different points of view.

There was positive change in explanation for the participants' views of the subjective (theory-laden), and social and cultural NOS. Participants increased from 16% to 91% exhibiting adequate explanations of the subjective NOS, and at the conclusion of the study the 91% of the participants explicated adequate understandings of the social and cultural NOS. These participants noted that scientists' prior knowledge, personal backgrounds, and viewpoints, and other "human" elements influenced how they interpreted data:

ST_{10}: The science put forward quite different conclusions about the same events due to that scientific research is conducted in different kinds of contexts based on the culture and values. While a scientist works on a problem, he/she can not be absolutely objective and realist. The impressions of the past experiences force him/her to quite different. For example let's think a box and throw a thing into it. To the question of "what is there in the box?" everybody will provide different answers when its inside is not opened. …. If science is universal everybody would make the same interpretation. Thus I believe science is affected by social and culture values.

ST_{12}: The science reflects social and cultural values. Because scientist hold prejudices, some traditions, values in the society in which he grew up. Scientist can not be absolutely neutral…

In the second part of the study elementary student teachers were supported to develop an activity in which they can teach any of the NOS component to elementary students. In this way I planned to encourage them to teach NOS. NOS teaching materials which were developed by the subjects as a compulsory work of the STSC are presented and introduced in the Appendix.

It is concluded from the report analyses of eleven NOS activities that six of the student teachers in sequence adopted inferential, subjective/social-cultural, and tentative NOS and one of them adopted only empirical nature of science.

From the research reports and also presentations of them in the STS course, it was revealed that for student teachers to teach NOS to elementary students is really interesting, amusing and is not found difficult to achieve. In addition to this it was seen that they all started to implement their teaching materials with nearly the same questions which were used in the "cube" activity. These are: what is science?; how does a scientist work?; what does a scientific work mean? . While they presented and shared their research findings with the STS class, the first researcher and also the course instructor asked them to explain discuss their findings. ST_8 who had adequate understanding about all the NOS aspects at the end of the study stated as;

"You while teaching the NOS to us started asking those questions and assessed our initial views about science and scientists and we really interested in the topic. Thus while implementing my activity in the real learning environment I aimed to start as we practiced. This was really a sigthful experience for me especially when

> encouraging my students into my activity and assessing their pre-views on the NOS" (ST_8).

Throughout the activity presentations when student teachers were asked if they would teach the NOS to their students when they begin teaching elementary students, all responded positive.

> ST_5: I really want to teach my students the NOS. I believe that I did not know the real NOS since now. It is different from what I thought I knew. Science teaching must begin with teaching the nature at first. This will encourage students to get interested in learning science.
>
> ST_7: The NOS is not difficult to teach. With little time and effort, I can teach it to my students. I think teaching program's structure does not limit its teaching, indeed it encourages it...I also think science teaching program supports us as teachers to teach it to elementary students.

Even though student teachers expressed strong beliefs to teach it in the future, we do not know if this will really be the fact. This assertion is needed more research and data. We have planned communicating with student teachers, who are now at their last years of the teacher education program, and we will research how they will teach the NOS after they begin teaching formally.

Discussion

Previous research has shown that elementary teachers typically have misconceptions related to NOS prior to interventions (Abd-El-Khalick, 2001; Akerson et al., 2000; McComas, 1996). The participants of this study held naïve views of nearly all of the investigated aspects of the NOS at the beginning of the study, however they changed their views toward the "adequate" views after the intervention. For example, misconceptions about the relationship of observations and inferences ignore the inferential nature of science, with teachers tending to believe that one must be able to ''see'' or directly sense something in order to know its meaning (e.g., to know what an atom looks like someone must have seen it through a microscope). The findings of this study support this claim. Likewise, only 16% the participants held adequate views of the inferential nature of science. It is surprising given that most of them explained scientists conduct experiments. However, they maintained that A scientist really know what an atom looks like as the model IS based on experimental results. Only two of them believed that by experimenting scientists find clues, interpret them and reach that model. It can be said that participants know that scientist are conducting experiment however this does not mean they know experimental nature of science. They thought that scientists does experiments and reach the model which explicitly reflects the atoms inner structure. However at the conclusion of the study, most of them (66%) expressed adequate views about the inferential nature of science. For example a participant expressed that "…the structure of an atom was modeled as experimental evidences, observations and inferences…" (ST_{2post}). Thus when we asked him in what way he learned the inferential NOS he also like the others especially indicated the Tricky Tracks! and Hypothesis

Boxes activities. It is also important to mention that participants in the current study are in their third year of teacher education program. It is known that participants have experienced many experiments related to science individually, especially at their second school year, in a "science practice course". This course is compulsory for all of the participants and they are responsible for planning and implementing a science experiment by presenting in the laboratory to their classmates. Most of them included that students make observations and try to understand what is really happening that are known as inferences. However those activities could not provide them to know the inferential NOS until the STS course in which explicit NOS teaching was applied. This informs us that the NOS is needed to teach in an explicit-reflective way to elementary student teachers likewise the others (list here those "others") and to make a connection between the NOS activities and scientific knowledge.

It was found that all participants explicated inadequate views about the relationship between theories and laws at the beginning of the study. Most of them explained that laws are "proven" to be true while theories are not "proven". The others believed in a hierarchical relationship between theories and laws whereby theories become laws with the accumulation of supportive experimental results. They explained that a theory is simply "somebody's idea" of what has happened and it has a potential to change in the future. However, scientific theories are well established explanations of natural phenomena (Lederman & Abd-El-Khalick, 1998; Sandoval & Morrison, 2003). The view "scientific laws can be "proven" and/or are not liable to change" indicates that participants thought scientific knowledge was absolute. It is obvious that the participants believed that "scientific laws are accepted as correct by everyone and it does not change..." as how it was indicated by one of the participant (S_6). It can be concluded here that although the participants believed scientific laws do not change in the future, though scientific theories do. Thus they did not understand the difference between them, for example theories and laws are different kinds of knowledge. Only one student explained that "…theories are suspicious truths however laws are accepted certain facts…. Theories can be destroyed easily; on the other hand, laws can not…". However there are a lot of scientific theories which could not destroy up to know for example related to disappearance of dinosaurs. It is also important that many participants who thought that theories did change believed that theories can change into laws. The hierarchical notion of that a theory can transformed to a law when there is enough evidence is hold by all of them at the beginning of the study. This may also be the result of teaching of scientific method. For example one of the participant response to the question related to scientific method clarifies this notion. "Scientific method is rules and methods that progress step by step which scientist must use while doing research. I believe all scientific research use the scientific method" (ST_{7pre}). This issue is really discussed and it is suggested not to teach students and student teachers scientific method as the explained way. There is not a unique and universal method to conduct scientific research. The participants all thought that if scientist could not use a universal scientific method that progress step by step, they would not reach a true knowledge. This result is also discussed with preceding studies (Lederman & Abd-El-Khalick, 1998; McComas, 1996). This may be because of the fact that science and scientific knowledge is formally taught in schools in that way. That is to say if someone wants to do scientific research he/she surely pursuit scientific method, otherwise he/she will reach neither no where nor a knowledge which is not accepted by scientific society.

The participants changed their views and the 41% of them adopted the view that scientific theories and laws are different kinds of knowledge and that one does not develop in the other. They also all understood the difference between the two kinds of knowledge structure and importance of teaching the difference between theories and laws to help their own students develop an adequate understanding of science. Nevertheless they could not describe the meanings of those sufficiently. It is really difficult to teach the difference between a scientific theory and law to individuals. In the content of STS course the participants were informed within the activities about the definitions of a scientific theory and law referencing to some scientific knowledge for example kinetic molecular theory, evaluation theory and Newton's Laws and universal gravitational law. However we think that further efforts are required to teach the difference between the two kinds of knowledge.

None of the participants held adequate views of the empirical NOS and explicated exactly that the empirical NOS sets science apart from other disciplines. Here it is important to mention that most of them noted that science includes experiments and these experiments can prove the suggested knowledge to embed its truth. However, it is critical to draw a conclusion that they know the empirical NOS for them to use the terms of "data", "proof" or "evidence" in both questionnaires and interviews. The majority of them also held inadequate views of NOS as tentative. 16% of them explained that scientific knowledge can change in the future but they could not explained exactly how it could. The main reason for this new knowledge is found everyday so the amount of scientific knowledge increases. However they could not explained that scientific knowledge can change by looking at the old data in the light of new view points and theories. They all, including the two discussed preceding a few sentences believed that scientific laws are proven and do not change. This shows that they do not understand the tentative NOS explicitly. The explicit-reflective NOS teaching in the STSC supported the student teachers to understand both tentative and empirical nature of science. 83% of the participants hold more adequate views of the tentativeness of scientific knowledge. In this time they often reported that the reason for a change in a scientific knowledge was due to new evidence which can create better explanations. The participants also expressed a view that all scientific knowledge was subject to change and could change not just via a modification of current ideas but also the replacement of current ideas with ones based on better evidence. In this benefit we think the cubes activity played the critical role. In the content of this NOS activity the participants researched number under the cube and changed their views when they obtained a new data. Then the instructor of the STS course purposefully supported the student teachers to make a connection between the activity and the science referencing to the "Universal Gravity Law" from Aristotle to Einstein. In the benefits of the participants about the tentative and empirical NOS which is higher than the other studies (Cohern & Loving, 2002; Matkins, Bell, Irving, & McNall, 2002) this initiatives should make an extra contribution.

Moreover, the majority of participants did not demonstrate adequate understandings of the role of human inference, imagination and creativity in generating scientific claims, or the subjective (theory-laden) nature of science. The participants (%84) did not appreciate the creative work in searching for patterns in data or developing models and theories. For the two students who did believe that scientists used creativity, they believed more of the role of inventiveness of new items or making presentations of their results, not of inventing ideas or models and explanations. It is also critical to explain here that five participants within the %84 group explained that scientists use their creativity and imaginations, however they could not explained sufficiently in which part of their study and how they use those abilities. Thus they were added to the group who do not have adequate understanding of this NOS aspect. However, at the conclusion of the study, a full 91% of them exited the course with more adequate understandings of the role of creativity and imagination in science. They understood that science, like art, required creativity and imagination. Although they all explained that scientists use their imaginations and creativity, they clarified that scientists mostly use those abilities while suggesting hypothesis than in all the processes of scientific research. This may be because of the teaching form of the NOS activities in the STSC. For example all the activities implemented in the course began with a direct question to solve, thus this should make them to use more creativity and imagination. However it is known that those human abilities are used in all the processed of scientific research. In some of the activities for example in Water Generator and the tubes students firstly took data and then tried to develop a model based on data and encouraged to use their imagination and creativity. The instructor also dwelled upon those abilities to construct a scientific model and the participants shared this vision. Nevertheless we think more direct connections are required to achieve this.

The participants (83%) failed to recognize the fact that scientists' personal experiences, preferences, and philosophical assumptions do influence their work at the beginning of the STSC. They believed that science and scientific knowledge are objective and they are not affected from subjective values such as experiences, preferences and philosophical assumptions of scientists. This is perhaps the result of an instruction in which science was taught to students as an objective way in the Turkish educational context. It is still a fact by the year 2007 that Turkish students are still taught science as being objective and there is a universal method to do science in the content of High School Biology 1 Course (Boru et al., 2001). Thus it is not surprising for student teachers to think that if someone else pursues the same ways as a scientist followed while finding a scientific knowledge, he/she will do and reach to the same. That is to say working in the same manner is resulted with the same outcome. On the other hand there was a positive change in explanation for the participants' views of the subjective (theory-laden), and social and cultural NOS from 16% to %91. This is the result of some activities in which the instructor supported to the student teachers to make a connection between the activity and subjective, social and cultural nature of science.

The results of this study indicated that the explicit-reflective NOS teaching in this STSC was "effective" at enhancing participant preservice elementary teachers' views. Participants made substantial gains in their understandings of the target aspects of NOS. It can be accepted basically as an achievement of explicit-reflective NOS teaching method. It can be claimed that student teachers found an opportunity of making a close connection between the activities presented in the STSC and scientific endeavor. That is to say student teachers are supported to what they experienced throughout the activities is what scientists really have done during their scientific investigations. This is an important chance for the student teachers to construct a link between the activities and scientists' real experiences. Thus, participants loaded many meanings to all positions they experienced during three months STS course. The only way to teach the aspects of NOS effectively to student teachers can be the explicit-reflective teaching. Truly, unlike the preceding studies, most participants improved and showed substantial changes in almost al the aspects of NOS but especially in their absolutist views of scientific knowledge.

For elementary teachers or preservice elementary teachers to understand the NOS adequately does not always mean to that it would easily be taught to students (Lederman, 1999). However in the current study to embed student teachers' understanding the aspects of NOS and having strong beliefs to teach it, they were supported to implement and experience it in real educational settings. For a student teacher to experience something directly is quite important. Thus student teachers in this study had really strong beliefs to teach it. Literature includes research data that for a student teacher having strong beliefs toward science and scientific endeavor may help them better experience science. Four factors were identified as most influential in participants' teaching the NOS efforts (Lederman, Schwartz, Abd-El-Khalick & Bell, 2001). These are; (i) knowledge of NOS, (ii) knowledge of subject matter, (iii) pedagogical knowledge, and (iv) intentions towards teaching NOS. In this study intentions were found the most critical factor. In the current study elementary student teachers had strong intentions to teach it for their students because they had internalized the importance of teaching NOS. It is not certain whether substantial changes in elementary teachers' conceptions can be achieved in a single elementary method course, nevertheless, there is support for success in enhancing NOS conceptions in such a setting (Shapiro, 1996), particularly when using an explicit-reflective approach to help teachers develop more accurate conceptions of some NOS aspects (Abd-El-Khalick & Akerson, 2004; Akerson, Abd-El-Khalick & Lederman, 2000; Akerson & Abd-El-Khalick, 2003). Thus an explicit-reflective teaching approach was used in the study to achieve this and the obtained results are believed to support this view.

Implications for Teacher Education

The preservice elementary teachers in the current study held naïve views of all the aspects of NOS at the beginning of the study. This result is quite consistent with research in the related literature (Akerson et al, 2000; Bianchini & Colburn, 2000; Akerson & Abd-El-Khalick, 2000; Akerson et al, 2006; Macaroǧlu et al, 1998). The subject's views of science were also quite similar to those. For example Turkish primary student teachers' pre-views about science are not coherent to the NOS perspective. The main reason is that the Turkish student teachers severely believed that what science is, it is absolute knowledge. For that scientific knowledge could not be tentative because of the fact that science is an "objective endeavor". It is concerned with the generation of "certain" or "true" knowledge about the natural world. It is important that why they thought it is objective. Their beliefs toward to that such a "certain" or "true" knowledge is just achieved through the use of the "Scientific Method" and/or the reliance on neutral, objective observations about the natural world. This situation reflects naïve views of the theory-laden and empirical NOS whereby "certain" knowledge is developed by making theory-free or neutral observations of nature. Those are all misconceptions about the science which the Turkish preservice elementary teachers hold at the beginning of the study. However, several substantial and favorable changes in participants' conceptions of the target NOS aspects were evident at the conclusion of the taught STS course. These results substantiate our claim regarding the effectiveness of an explicit reflective approach in enhancing prospective elementary teachers' NOS views like the others (Abd-El-Khalick & Lederman, 1998). It is quite effective to teach NOS to elementary student teachers in an explicit-reflective way. However it is more difficult to have them implement it while student teaching. In the current study we taught NOS to the student teachers explicitly and then supported them to develop NOS activities in which what aspects they wished to include. Then they were said to teach it to elementary students in real educational contexts. Thus student teachers experienced both developing NOS activities and implementing them. This was an important experience for them to hold strong beliefs to teach it for their students in subsequent teaching life. By this way I truly believe that I achieved this based on student teachers' reflective notes on views about teaching NOS to students in one part of the activity report and also in their presentations. Now it is time to investigate whether they would really teach NOS aspects to their students or they would find enough time and spend enough effort to perform it as I hope.

References

Abd-El-Khalick, F., & Lederman, N. G. (1998, April). Improving science teachers' conceptions of the nature of science: A critical review of the literature. Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Diego, CA.

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. Science Education, 82, 417-436.

Akerson, V. L., & Volrich, M. (2006).Teaching nature of science explicitly in a first grade internship setting. Journal of Research in Science Teaching, 43, 377-394.

Akerson, V.L., Abd-El-Khalick, F.S., & Lederman, N.G. (2000). Influence of a reflective activity-based approach on elementary teachers' conceptions of the nature of science. Journal of Research in Science Teaching, 37, 295–317.

Akerson, V.L., Morrison, J.A., & McDuffie, A.R. (2006). One Course Is Not Enough: Preservice Elementary Teachers' Retention Of Improved Views Of Nature of Science. Journal of Research In Science Teaching, 43(2), 194-213.

American Association for the Advancement of Science. (1993). Benchmarks for science literacy: A Project 2061 Report. New York: Oxford University.

Barufaldi, J.P., Bethel, L.J.,&Lamb,W.G. (1977). The effect of a science methods course on the philosophical view of science among elementary education majors. Journal of Research in Science Teaching, 14, 289–294.

Bell, R. L., Lederman, N. G., & Abd-El-Khalick, F. (1998, April). Preservice teachers' beliefs and practices regarding the teaching of the nature of science. Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Diego, CA.

Bianchini, J.A. & Colburn, A. (2000). Teaching the nature of science through inquiry to prospective elementary teachers: A tale of two researchers. Journal of Research in Science

Teaching, 37, 177–209.
Bloom, J. W. (1989). Preservice elementary teachers' conceptions of science: Science, theories and evolution. International Journal of Science Education, 11, 401-415.
Boru, S., Ozturk, E., & Cavak, S. (2001). *High school biology I.* Istanbul: National Education Press.
Brickhouse, N. W. (1989). The teaching of the philosophy of science in secondary classrooms: Case studies of teachers' personal theories. International Journal of Science Education, 11, 401-415.
Brickhouse, N. W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. Journal of Teacher Education, 41, 53-62.
Brickhouse, N. W., & Bodner, G. M. (1992). The beginning science teacher: Classroom narratives of convictions and constraints. Journal of Research in Science Teaching, 29, 471-485.
Butts, D. P., Hofman, H. M., & Anderson, M. (1993). Is hands-on experience enough? A study of young children's views of sinking and floating objects. *Journal of Elementary Science Education, 5* (1), 50-64.
Çelik, S., Öğretmen Adaylarının Bilim Anlayışları ve "Fen, Teknoloji ve Toplum" Dersinin Bu Anlayışlara Etkisi. Unpublished Yayınlanmamış Master dissertation, Yüksek Lisans Tezi, Atatürk Üniversitesi, Turkey,Erzurum, 2003.
Cobern, W.W., & Loving, C.C. (2002). An investigation of preservice elementary teachers' thinking about science. Journal of Research in Science Teaching, 39(10), 1016-1031.
Flick, L. B. (1996). Understanding a generative learning model of instruction: A case study of elementary teacher planning. *Journal of Science Teacher Education, 7,* 95-122.
Gallagher, J. J. (1991). Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science. Science Education, 75, 121-134.
Gücüm, B., Fen Bilgisi Öğretmenliği Öğrencilerinin Bilimsel Bilginin Yapısını Anlama Düzeyleri Üzerine Bir Araştırma, IV. Science Education Semphusium, Fen Bilimleri Eğitimi Kongresi, Hacettepe Üniversitesi Eğitim Fakültesi, Turkey,Ankara, 2000.
Gürses, A., Doğar, Ç. & Yalçın, M. (2005). Bilimin Doğası Ve Yüksek Öğrenim Öğrencilerinin Bilimin Doğasına Dair Düşünceleri, Milli Eğitim Dergisi, 166.
Happs, J. C., & Scherpenzeel, L. (1987). Achieving long-term conceptual change using the learner's prior knowledge and a novel teaching setting. *Proceedings of the Second International Seminar of Misconceptions and Educational Strategies in Science and Mathematics, Volume II,* 170-181.
Hoffman, R. (1993). For the first time, you can see atoms. American Scientist, 81 11-12.
Kang, S., Scharmann, L.C. ve Noh, T. (2005). Examining Students' Views on the Nature of Science: Results from Korean 6th, 8th, And 10th Graders, Science Education, 89 (2005) 314-334.
Kılıç, K., Sungur, S., Çakıroğlu, J. & Tekkaya, C. (2005). Ninth Grade Students' Understanding of the Nature of Scientific Knowledge, Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 28, 127-133.
King, B. B. (1991). Beginning teachers' knowledge of and attitudes toward history and philosophy of science. Science Education, 75, 135-141.

Koulaidis, V., & Ogborn, J. (1989). Philosophy of science: An empirical study of teachers' views. International Journal of Science Education, 11, 173-184.

Lederman, N. G. (1992). Students' and teachers' conceptions about the nature of science: A review of the research. Journal of Research in Science Teaching, 29, 331-359.

Lederman, N. G. (2006). Research on Nature of Science: Reflections on the Past, Anticipations of the Future. Asia-Pacific Forum on Science Learning and Teaching, 7(1), p.2.

Lederman, N. G., & Abd-El-Khalick, F. (1998). Avoiding de-natured science: Activities that promote understandings of the nature of science. In W. McComas (Ed.), The nature of science in science education: Rationales and strategies. Dordrecht, The Netherlands: Kluwer

Lederman, N. G., Farber, P. L., Abd-El-Khalick, F., & Bell, R. L (1998). The myth of the scientific method and slippery debates in the classroom: A response to McCreary. *The Oregon Science Teacher, 39*(4), 24-27.

Macaroglu, E., Taşar, M. F. &ve Cataloglu, E., Turkish Preservice Elementary School Teachers' Beliefs about the Nature of Science. Annual Meeting of National Association for Research in Science Teaching (NARST), San Diego, CA, 1998.

Matkins, J.J., Bell, R.L., Irving, K., McNall, R. (2002). Impacts of contextual and explicit instruction on preservice elementary teachers' understandings of the nature of science. *Proceedings of the 2002 Annual International Conference of the Association for the Education of Teachers in Science*. Pensacola, FL: Association for the Education of Teachers in Science.

McComas, W. (1996). Ten myths of science: Reexamining what we think we know about the nature of science. *School Science and Mathematics, 91*(1), 10-16.

Meichtry, Y. (1995). Elementary science methods strategies to measure and develop student views about the nature of science. Paper presented at the annual meeting of the Association or the Education of Teachers in Science, Charleston, WV.

Moss, D.M., Abrams, E.D., & Robb, J. (2001). Examining Student Conception of the Nature of Science, International Journal of Science Education, 23, 8 (2001) 771-790.

National Research Council. (1996). National science education standards. Washington, DC: National Academic Press.

Oyman, N.Y., İlköğretim Fen Bilgisi Öğretmenlerinin Bilimin Doğası Hakkındaki Anlayışlarının Tespiti. Unpublished Master dissertation, Marmara Üniversitesi, Turkey, 2002.

Popper, K. L., The Logic of Scientific Discovery. NewYork: Basic Books, 1959.

Sandoval, W. A., & Morrison, K. (2003). High school students' ideas about theories and theory change after a biological inquiry unit. Journal of Research in Science Teaching, 40, 369–392.

Strauss, A. & Corbin, J., Basics of Qualitative Research: Grounded Theory Procedures and Techniques. Ondon, Sage Publications, 1990.

Strike, K. A., & Posner, G. J. (1992). A revisionist theory of conceptual change. In R. A. Duschl and R. J. Hamilton (Eds.), *Philosophy of science, cognitive psychology, and educational theory and practice* (pp. 147-176). New York: State University of New York.

Yakmacı, B., Fen Alanı (Biyoloji, Kimya Ve Fizik) Öğretmenlerinin Bilimsel Okur-Yazarlığın Bir Boyutu Olan "Bilimin Doğası Ve Özellikleri" Konusundaki Görüşleri. Unpublished Master dissertation, Boğaziçi Üniversitesi, Turkey, 1998.

Appendix

NOS Materials of the Subjects

	Name	NOS Concept	How Effective Is the Material?
ST_1	-	-	-
ST_2	Look at my pictures!	Observations are different from inferences. Science is subjective.	Students looked at the six different pictures and explained what they see on them and then what they understand from them. Then I taught them what they see on them are observations and what they think about them are inferences. From moving different inferences they realized that science is not objective.
ST_3	What is there in the pictures	Observations and inferences are different kinds of knowledge.	Students examined at the pictures in sequence and understand that observation is what you really see at the data, however inferences are what you think what can be in the pictures.
ST_4	Look at my material!	Observation is not the same with inferences. Scientific knowledge is not objective.	I asked students what they see and in the first phase they all explained their inferences about it. I again asked what they really see, this time they answered a balloon and a small ball. I explained them « yes this is what really you see ». I turned back to their first answers as sun, moon, sun system etc. and explained those all their inferences. I also taught that scientific knowledge is not objective moving from their different inferences about the material.
ST_5	Mysterious box	Science is not certain and it has probability	Students said that what is inside the box and what kind of system is there in it can be known just as they open and look at it otherwise not. They understand that science is not certain and has probability.
ST_6	Look at the picture!	Observations and inferences are different kinds of knowledge.	Students examined at a picture and understand that observation is what they see in the first phase on the picture, however when they interpret the picture in the manner of story this time it is a inference.
ST_7	Which line is longer? Thin or thick line	Science is explanation of events. However we can not perceive everything as they are in reality every time such as illusions.	Students realized that feelings, emotions and perceptions about examined events may mislead us; scientific data can include those all thus illusions are inevitable.
ST_8	Why this child is crying?	Science is subjective, is not certain, and needs empirical evidences.	I asked students that « what do you see in the picture? » They answered as a crying child. I asked how you can say he is crying. They answered there are tears on his face and his face look like as HE WAS CRYING trying. I asked why you think he is crying. They explained some reasons as HE hi is lost, school repot REPORT is not good, he experimented a natural disaster etc. referencing to their explanations I taught them observations as they

			really see on the picture, empirical NOS as their data (tears on) about the crying child, inferential NOS as their explanations as why this child is crying, and subjective NOS as their different inferences about child.
ST_9	Look at the picture!	Observations are different from inferences and science is not objective.	I showed students eleven pictures and asked them what you see on them in sequence and then asked them what they think there is being on them. Moving from here they understood that observations are what they really see on them, inferences are what they interpret about time. I also taught them science is not objective and can change according to a person to the other referencing their different inferences.
ST_{10}	Black box	Science is not certain and it has probability.	From moving student's different views about the inside of the box, I asked them can you surely say that there is something in it as ı drawn. They said that we can not say that it is really as we drawn. Thus, they understand that scientific knowledge is not certain and has probability. Thus it can change in time.
ST_{11}	The abstract pictures	Science has probability, subjective and culturally embedded.	Students looked at the four different abstract pictures and explained that they see different things on them. These views were very different according to students' cultures, thus I explained them « if you can see different things on them so, scientist also can see ». Thus science has probability and scientific knowledge is subjective and related to society's cultures and socially structures.
ST_{12}	Mysterious pictures	Observations are different from inferences and science is not certain.	Students looked at the different pictures and explained what they really see and though out what could be on the pictures. In the first phase they explained that they see different things. However these all their inferences. I asked them what really they see; this time they answered some signs. I taught them seeing is what is really on the picture, and inference are what they guess what could be done on the picture. I also taught them science is not certain moving from their different observations and inferences about the picture.