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How do Science Teachers View and Teach the Nature of Science? A Classroom Investigation

Fen Öğretmenlerinin Bilimin Doğası Görüşleri ve Öğretimleri Nasıldır? Bir Sınıf İçi Araştırması

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Abstract

The purposes of this study were to investigate science teachers' nature of science (NOS) views so as to determine how their views influence their instructional practices. Seventy four science teachers and five teachers in a big city in Turkey were selected purposefully as the sample of this study. A sub-set of 18 relevant items from Views on Science-Technology-Society (VOSTS) Questionnaire were used to assess teachers' NOS views. Semi-structured interviews and class observations were conducted with these five "case" teachers in order to allow them fully express their views and instructional practices. The data analysis revealed that the participating science teachers held naïve views on many dimensions of the NOS. Furthermore, it was found that teachers' views did not directly influence their classroom practices. We also observed that the perceived curriculum, the high stakes examinations, expectations of school administrators, students, and parents were the most important factors influencing teachers' decisions regarding classroom practices.

Keywords: Nature of science, classroom practices, in-service teachers, multiple-case study

Öz

Bu araştırmanın amacı, fen öğretmenlerinin bilimin doğası hakkındaki görüşlerini incelemek ve bu görüşlerin onların sınıf içi uygulamalarını nasıl etkilediğini belirlemektir. Araştırmanın katılımcıları Türkiye'deki bir büyükşehirde görev yapmakta olan 74 fen öğretmenidir. Öğretmenlerin bilimin doğası hakkındaki görüşleri, literatürde kısaca VOSTS olarak bilinen Bilim-Teknoloji-Toplum anketinden seçilmiş olan 18 madde ile değerlendirilmiştir. Öğretmenlerin görüşlerini sınıf uygulamalarına nasıl yansıttıklarını belirlemek amacıyla gönüllülük esasına dayalı olarak durum çalışmasına alınan beş öğretmen ile yarı yapılandırılmış görüşmeler ve sınıf içi gözlemleri gerçekleştirilmiştir. Veri analizleri sonucunda, katılımcı öğretmenlerin bilimin doğasının birçok boyutu hakkında naif görüşlere sahip oldukları ortaya çıkmıştır. Aynı zamanda öğretmenlerin bu görüşlerinin sınıf uygulamalarına doğrudan etki etmediği görülmüştür. Katılımcı fen ve teknoloji öğretmenlerinin sınıf içi uygulamalarını belirleyen en önemli etkenlerin başında algılanan müfredat, okul idarecileri, öğrenci ve velilerin istek ve beklentileri ile sınav sistemi gösterilebilir.

Anahtar Sözcükler: Bilimin doğası, sınıf uygulamaları, fen öğretmenleri, çoklu durum çalışması

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Introduction

Attempts to understand the nature of science (NOS) date back to early 1900s (Lederman, 1992) when understanding the NOS was deemed equal to understanding scientific processes and methods. Textbooks and school curriculum's portrayal of characteristics of science heavily relied on traditional (Baconian) views and described scientific knowledge as being absolutely true, objective, developed by induction and not connected to human creativity and/or imagination (Haidar, 1999). In 1960s, the purposes of teaching the NOS focused on inquiry and science process skills. Since 1980s, psychological and sociological factors have become dominant in describing the NOS. These factors are theory-ladenness of observations, the role of human beings in the development of scientific explanations, the social structure of scientific organizations and the role of social statements in evaluating scientific claims (Abd-El-Khalick & Lederman, 2000). Today, teaching the NOS is highlighted as an educational aim in many educational reform movements and the curricula of many countries around the world (Lederman, 2007).

In Turkey, the vision statement of the current integrated science curricula for grades 4-8 is expressed as *"all pupils, irrespective of their personal differences, should be raised as science and technology literate"* while the term "scientific literacy" can be defined in various ways. The definition of the term in Turkish curricula includes an understanding of NOS, having scientific calculation ability and positive attitudes towards science, having basic scientific knowledge and understanding the relationship between science and society (Ministry of National Education [MNE], 2005: p. 5).

Despite radical changes made in the science curricula in 2005, national and international indicators show that there is much gap for progress in science education in Turkey. In centralized countrywide exams, primary and secondary school students' success scores in science are very low (Ozden, 2007). The same is true for international comparison tests such as TIMSS (Acat, Şişman, Aypay and Karadağ, 2011; Uzun, Bütüner, and Yiğit, 2010) and PISA (MEB, 2007; Anıl, 2009).

Due to the assumption that teachers' views and beliefs influence their behaviors (Pajares, 1992), there has been a growing interest among researches in determining the relationships between teachers' views about the NOS and their instructional practices (Brickhouse, 1990; Duschl & Wright, 1989; Gallagher, 1991; Mellado 1997; Mellado, Bermejo, Blanco, & Ruiz, 2007). Although there were many studies tackling the relationship between teachers' beliefs and their educational practices, there is no consensus on this issue which led to the assumption that teachers' classroom practices could be affected by many factors including their views on the NOS. Thus, a gap in the literature emerged leading to the idea that more studies at different levels with different variables are needed (Lederman, 1992; Melloda et al., 2007).

Many researchers have the idea that teachers' beliefs about the NOS are not an explanatory factor of their educational practices (Abd-El-Khalick, Bell & Lederman, 1998; Duschl & Wright, 1989). In contrast, other researchers claim that teachers' knowledge and beliefs directly affect their educational practices (Brickhouse, 1990; Gallagher, 1991; Palmquist & Finley, 1997). Despite these two opposite perspectives, the common conclusion of such research studies is that both in-service and pre-service teachers do not possess adequate understanding of the NOS. Therefore, before investigating the relationship between teachers' views and their instructional practices, their views on the NOS should be carefully examined. After that, how these views are becoming visible in classroom practices should be revealed in detail and instructional practices should be adjusted thereafter accordingly.

According to Akerson and Abd-El-Khalick (2003) found that teachers needed support to translate their NOS views and intentions into pedagogically appropriate instructional activities that would make the targeted aspects of NOS accessible to her students. The concluded that understandings and intentions were necessary to enable teachers to teach about NOS. Likewise, Akerson and Hanuscin (2007) obtained improved student learning as a result of teacher learning of NOS supported with pedagogical tools in a long term professional development program.

Today's NOS perspective is far from the general positivist point of view. Today, NOS is described in a post-modern framework based on the views of philosophers such as Kuhn and Hanson and the relativistic structure of science. According to such a post-modern understanding, science is a subjective human endeavor dependent on theory and culture, while at the same time, relies on experimental observations (Schwartz, 2004).

For explicitly explaining the aspects of NOS, Abd-El-Khalick and others (1998) lay out that such characteristics stem from the historical development of scientific knowledge and are related to pupils' daily lives. Such characteristics are also emphasized in reform documents (AAAS, 1993; NRC, 1996) and include the following: tentative nature of scientific knowledge; based-in experiments (obtained from the observations of world and/or based on observation); subjective (science is affected from people's past experiences); partly including human creativity and imagination (invention of explanations); having social and cultural context; the discrimination between observation and deduction (scientific knowledge is partly the function of each of them); and understanding the relationships between scientific theories and laws.

Studies on students' views about the NOS indicated that students generally do not have a desired level of understanding of what the NOS is (Bell, Blair, Crawford, & Lederman, 2003; Dogan, 2011; Kang, Scharmann, & Noh, 2005; Lederman, 2007; Moss, Abramsand, & Robb, 2001; Solomon, Scott, & Duveen, 1996). Students think that scientific knowledge is absolutely true. They believe that the fundamental interest of scientists is gathering and classifying facts in order to uncover the laws of nature. According to students, hypotheses can be proven. In addition, students have inadequate understandings about creativity in science, research programs being guided by theories, and the differences between experiments, models, hypotheses, theories, and laws. They also have inadequate understandings of the relationship between and interdependence of different branches of science. According to Lederman (1992), the reason of this inadequacy is that even children who display a great interest in science have inadequate knowledge about what it actually is.

The results of above-mentioned studies triggered researchers to focus firstly on teachers as responsible for this inadequacy through their classroom practices. Research on in-service and pre-service teachers revealed that they do not have adequate understandings of the NOS either (Abd-El-Khalick & BouJaoude, 1997; Dogan & Abd-El-Khalick, 2008; Haidar, 1999; Murcia & Schibeci, 1999; Rubba & Harkness, 1993; 2001; Yakmaci, 1998, Tasar, 2006).

Dogan and Abd-El-Khalick (2008) aimed to assess 10th grade Turkish students' and science teachers' conceptions of NOS and whether these conceptions were related to a set of selected variables. The researchers categorized participant responses as ''naïve,'' ''have merit,'' or ''informed,'' and compared the frequency distributions for these responses for various groupings of participants. According to their research results, majority of participants held naïve views of the majority of the target NOS aspects. Teacher views were mostly similar to those of their students. Similar results were reported by Yakmaci (1998) in her study of science teachers' (biology, chemistry and physics) views on the NOS. Abd-El-Khalick and BouJaoude (1997) used VOSTS items to assess the NOS views of 20 in-service secondary science teachers in Lebanon. They reported that participants' NOS views were fluid and lacked coherence. Although all participants expressed some views that were consistent with current conceptions of NOS, the larger majority held naïve views of crucial NOS aspects. Haidar (1999) examined pre-service and in-service teachers' conceptions on NOS in the United Arab Emirates. The author reported that participants' views were neither distinctly traditional nor constructivist in nature. In their research, Murcia and Schibeci (1999) reported that 73 pre-service primary teachers' conceptions on NOS clearly were not in accord with modern views.

By taking these research studies on NOS into account, teachers' conceptions on NOS and teaching NOS are considered to be very important. Having teachers' understanding of the NOS and nature of scientific knowledge at a desired level and also have them transfer these understandings into their classroom practices are crucial for attaining scientific literacy (Tuan & Chin, 1999).

The research question

Recent studies suggest that teachers' views and beliefs have an impact on their understanding of what good teaching is while influencing the way they construct their teaching/learning environments and practices. However, the suggestions given in the literature about this question are based more on theoretical discussions rather than observational data on teachers' actual classroom practices. Thus, the overarching research question of this study was as follows:

What are science teachers' views about the nature of science (NOS) and how these views influence their instructional practices?

Method

Design of the study

The current research study involved five science teachers who were selected from among larger group of 74 teachers working at 46 different primary schools in a large central Anatolian city of Turkey. Teachers' views about NOS were obtained by using a Turkish translation of a questionnaire which was constructed by selecting 18 related items from *Views on Science-Technology-Society* (VOSTS) questionnaire. VOSTS includes overall 114 items. The classroom observations were performed with the aim of gaining in depth insights into the teachers' classroom practices. The observations took place in grade 6 classrooms during teaching of the textbook unit entitled "the particulate nature of matter".

Contrary to single case study designs (e.g. Tasar, 2001) the methodological design of this research study resembles that of Taylor's (2001), Yalvac's (2005), and Ruffus Doerr's (2010), and Saad and BouJaoude's (2012) in which multiple cases were investigated collectively to reach a holistic view of the problems investigated. Thus, in this research study, classroom practices of five science teachers were analyzed individually as separate case studies. Hence, each science teacher case forms one unit of analysis (five in total). Afterwards, teachers were evaluated collectively to compare each one to others as in "collective multiple-case designs". The significant issue in this type of research design is that the researcher gathers data and evaluates each case by focusing on the same points. Similarly, in this study, five science teachers with different characteristics and forming different cases were evaluated in themselves and then these analysis units were compared to one another.

Participants

The purposes of qualitative and quantitative research studies are quite different. Hence, researchers using one of these methods follow different procedures in order to select their participants (Bogdan & Biglen, 1992; Denzin & Lincoln, 2000, p. 3; Patton, 1990, p. 169). In qualitative research, we no longer talk about a sample, but rather participants who are not selected randomly to represent a population. Instead, a researcher selects participants, who can provide rich and thick knowledge for the case(s) in hand, in a careful and purposeful way (Patton, 1990, p. 169). In order to fulfill these conditions, purposeful sampling was used while selecting participants in the current study in order to enable the researcher to choose better informants to achieve the research aims (Patton, 1990, p. 169).

Firstly, 74 (36 females and 38 males) science and technology teachers' NOS views of were probed. At the time they worked at 46 different primary schools in a central Anatolian, industrialized, metropolitan city. These were the schools for which we could get permission for the research from Turkish Ministry of Education. Secondly, five teachers were selected from among the initial group of 74 teachers in order to investigate the effects of teacher views on classroom practices. The focus group included 3 female and 2 male teachers. In selecting the focus group teachers, different selection criteria were considered such as the followings: having realistic views according to VOSTS questionnaire results, being experienced in teaching, being a teacher of 6th grade during the study, being available for qualitative data collection, and volunteering for the study. None of these teachers had taken any courses or in-service training seminars related to NOS. The demographic data of these teachers are given in Table 1. Teachers' names used in this manuscript are nicknames given by the researchers.

Table 1.

Some characteristics of the case study participants

Teacher	Gender	Faculty Graduated	Major	Teaching Experience (Years)
Melih	Male	Faculty of Science	Chemistry	12
Ela	Female	Faculty of Education	Physics	13
Hakan	Male	Faculty of Education	Chemistry	10
Ceren	Female	Faculty of Science	Physics	12
Nil	Female	Faculty of Education	Chemistry	12

Instrument and Procedures

In this study, classroom practice of each science teacher was initially regarded as a separate case study. Thus, each science teacher under investigation constitutes a unit of analysis. Afterwards, the data were re-evaluated to reach a holistic view. To do that, we compared each one to one another in a "holistic multiple-case design". The significant issue in this design is that the researcher gathers data and evaluates each case by focusing on similar issues.

In qualitative studies, researchers employ the triangulation method in order to test the validity of the results. The data triangulation took place in this study by collecting data for teachers' NOS views from VOSTS questionnaire and from interviews. In order to gain knowledge about classroom practice, in addition to interviews, teachers were observed during their classroom teachings. Moreover, a document analysis was employed to see how teachers utilized their NOS ideas in student performance tasks.

Views on science-technology-society (VOSTS) questionnaire

A shorter 18-item questionnaire was obtained from the 114-item VOSTS questionnaire (Aikenhead, Fleming, & Ryan, 1989). For the 18 items used in this study, the original item numbers in the Aikenhead and others (1989) are included in Table 2 and Table 3.

In the item selection process, we paid attention to the most frequently used topics in the literature for similar purposes. The selected 18 items were first translated into Turkish. In the translation process, the "back-translation technique" was used as suggested by Brisln et al., (1973). This technique is necessary to justify the equivalence of the source and target languages and to prove the qualification (as cited in Maneesriwongul & Dixon, 2004). In the translation process, 2 science education experts, 3 foreign language experts, and 2 Turkish language experts worked together. Moreover, a permission to use the VOSTS items were obtained by e-mail from one of the original developers of the questionnaire (Glen S. Aikenhead) and his views and suggestions concerning the research process were also taken into account. Aikenhead stated that the statements in the original questionnaire were completely taken from students' own statements. He declared that the same instrument could be used for pre-service and in-service teachers without any changes, by doing pilot study on the target group first.

The VOSTS questionnaire was firstly administered to 48 teachers who work at 25 public middle schools that were included in the pilot study. The data analysis revealed that among 864 (18x48) answers, only 41 answers (4.75%) included one of the three choices which is continually repeated in all items of the questionnaire. This ratio is quite lower than the ratios published in literature (i.e., Aikenhead, 1988 [12%]; Lieu, 1997 [5.93%]; Rubba, Bradford, & Harkness, 1996 [10.03%]). Thus, it was decided that, with some modifications, this questionnaire could be used for assessing teachers' views.

Classroom observations

Observational data collection took place during the teaching of the textbook unit of "The Particulate Nature of Matter" in grade 6. Each one of the five science teachers were observed for at least 8 weeks (4 hours per week) by the first author.

Semi-structured interviews

Interviews were conducted with these five teachers after initially after administration of the VOSTS questionnaire and finally after classroom observations. During the interviews, several questions were asked in order to understand the teachers' views on science education, students, science classes, and NOS and the inclusion of these views during class teachings.

Document analysis

In order to determine how participating teachers were assessing and including the NOS in student artifacts like projects, tasks, classroom activities, home works, examinations, and tests related documents were examined and analyzed.

Data Analysis

The teachers' categorized responses to the selected VOSTS items are shown in Table 1. There is no true or false type of categorization for the listed choices of the VOSTS items. However, in order to be able to interpret teachers' stances, each listed choice was categorized either as *Realistic*, *Plausible* or *Naïve* as done by Rubba et al. (1996) and Vazquez-Alanso & Manassero-Mas (1999). A panel of experts worked on the selected VOSTS items to form the categorization for each item choice.

According to the classification done by the expert panel a *realistic view* indicates an appropriate and contemporary view about NOS. A *plausible view* indicates an unrealistic but logical view, and lastly a *naïve view* indicates a non-realistic or non-acceptable view. The usual choices of "I don't understand" and "I don't know enough about this subject to make a choice" are the last two choices of each item and they were classified as naïve views. The choice "none of these choices fits basic viewpoint" was not included in any of the categories (Vazquez-Alanso & Manassero-Mas, 1999). Descriptive analysis and content analysis were done on data from classroom observations, the interview recordings, and student artifacts and documents.

Findings

Below we present the findings obtained in this study to answer the research question.

Teachers' Views on NOS

The VOSTS data were categorized according to the expert panel recommendations as realistic, plausible or naïve. The teacher (N=74) responses for each item are presented as percentages and frequencies in Table 2. Here, the most dominant category for each item are shown in bold type set.

Table 2 reveals that almost all teachers in the naïve category think that hypothesis evolve into theories and theories evolve into laws. The latter happens when they are proven true (95.9%; item 9). Besides, it is seen that teachers have naïve views about the epistemological structure of scientific knowledge. In addition, we may infer from Table 2 that great majority of teachers think that laws exist in the nature and they are discovered by scientists (items 15, 16, 17). The view that scientific models are the copies of the reality is the one mostly supported (64.9%; item 6).

Again a great majority of the teachers (79.7%) think that scientific knowledge change in the future (item 8). This view contradicts with the responses to items concerning hypothesis, theory and laws because in these items teachers share the idea that a theory can become a law if proven and laws no longer change.

In Table 2, we see that teachers have different views for different categories as revealed by the VOSTS items. They held naïve views in dimensions such as; scientific models, hypothesis, theory and laws, scientific assumptions, the epistemological structure of scientific knowledge (laws, hypotheses, theories) and paradigms of interdisciplinary concepts.

Table 2.

Categorized distribution of teachers' responses to the VOSTS items (N=74)

The Original Item Number and Relevance	Naïve		Plausible		Realistic		Collective Case study teachers' VOSTS responses				
	f	%	*f*	%	*f*	%	**Melih**	**Eda**	**Hakan**	**Ceren**	**Nil**
10111. Defining science	3	4,1	**53**	**71,6**	18	24,3	Plausible	Plausible	Plausible	Realistic	Plausible
20711. Influence of society on science	0	0	33	44,6	**41**	**55,4**	Realistic	Plausible	Realistic	Realistic	Realistic
40111. Influence of science on society	21	28,4	**47**	**63,5**	6	8,1	Realistic	Naïve	Plausible	Plausible	Realistic
60211. Characteristics of scientists	21	28,4	**53**	**71,6**	3	4,1	Realistic	Realistic	Realistic	Realistic	Realistic
90111. Nature of observations	30	40,5	-	-	**44**	**59,5**	Realistic	Naïve	Naïve	Plausible	Plausible
90211. Nature of scientific models	**48**	**64,9**	2	2,7	24	32,4	Realistic	Naïve	Naïve	Naïve	Plausible
90311. Nature of classification schemes	16	21,6	6	8,1	**52**	**70,3**	Naïve	Realistic	Plausible	Plausible	Plausible
90411. Tentativeness of scientific knowledge	15	20,3	**-**	**-**	**59**	**79,7**	Realistic	Realistic	Realistic	Realistic	Realistic
90511. Hypotheses, theories and laws	**71**	**95,9**	-	-	3	4,1	Naïve	Realistic	Plausible	Plausible	Plausible
90521. Role of assumptions	**32**	**43,2**	21	28,4	21	28,4	Realistic	Realistic	Realistic	Realistic	Realistic
90541. Nature of scientific theories	18	24,3	-	-	**56**	**75,7**	Naïve	Realistic	Realistic	Realistic	Realistic
90621. Rejection of a stepwise procedure, "the scientific method" as a writing style	28	37,8	**32**	**43,2**	14	18,9	Naïve	Plausible	Plausible	Plausible	Naïve
90651. Nonlinearity of scientific investigation	16	21,6	20	27,0	**38**	**51,4**	Realistic	Realistic	Realistic	Realistic	Realistic
90711. Precision and uncertainty in scientific knowledge	5	6,8	28	37,8	**41**	**55,4**	Plausible	Realistic	Plausible	Plausible	Realistic
91011. Epistemological status of laws	**56**	**75,7**	4	5,4	14	18,9	Realistic	Plausible	Plausible	Realistic	Plausible
91012. Epistemological status of hypotheses	**51**	**68,9**	15	20,3	8	10,8	Plausible	Plausible	Plausible	Naïve	Plausible
91013. Epistemological status of theories	**56**	**75,7**	18	24,3	3	3,8	Realistic	Plausible	Plausible	Plausible	Plausible
91111. Coherence of concepts across disciplines	**49**	**66,2**	17	23,0	8	10,8	Plausible	Naïve	Naïve	Naïve	Plausible

On the other hand, they held realistic views in the dimensions of the influence of society on science, nature of observations, nature of classification schemes, nature of scientific methods, tentativeness of scientific knowledge. Table 2 also includes the five teachers with whom we did interviews and classroom observations. Their NOS views are presented in the second part of Table 2.

Table 3 presents the teachers' naïve and traditional NOS views obtained in interviews. For example, while defining science, they refer to science as the process of finding and using knowledge in nature. The idea of discovering scientific knowledge existing in nature by doing experiments and using them in the way of simplifying daily life reflects a traditional point of view.

Understandings regarding scientific knowledge and its characteristics are described traditionally. They consider that experiments and observations are necessary to acquire scientific knowledge and knowledge can be valid only if it is justified by testing, and then proven and accepted by everyone. It is interesting to note that none of the teachers mentioned concepts like imagination or creativity.

According to the VOSTS data, it is seen that the 74 teachers held realistic views on tentativeness of scientific knowledge. However, the interview data indicates that they regard hypotheses and theories as subject to change but on the other hand see that scientific laws are the final (matured) stage of the scientific endeavor on a problem.

Likewise, the five collective study teachers share the idea that laws are proven type of knowledge that cannot change anymore. Furthermore, each of them mentioned the existence of a scientific method progressing step by step. These steps start with curiosity or interest in a research topic, and progress with forming a research hypothesis, doing observations and experiments, forming a theory, proving the theory with experiments and lastly obtaining laws.

Participants' Classroom Practice

For gaining a complete understanding of teachers' classroom practices, we examined their views about science teaching and learning, lesson plans, instructional methods and techniques, and assessments. For this purpose, the first author observed Melih, Ela, Hakan, Ceren and Nil's classroom teachings during the unit of "The Particulate Nature of Matter" for 8 weeks. The data were recorded in audio and observation sheets. The analyses and findings of these data are presented below.

The views on teaching science and learning science

Melih claimed that science education is necessary and these topics are essential for him. When he explained why science education was necessary, he asserted that by means of science education, a person can understand both himself and the outside world; by transferring the knowledge one learns, s/he can make life more meaningful and take advantage of it in many ways. **Ela** indicated that science education is necessary; students can transfer what they learn in this course into their daily lives and can benefit. According to Ela, the aim of a topic and where it will be used should be emphasized in a better way. She indicated that one of the topics she mostly focused on was providing students to take notes and listen to her. She claimed that she increases the success of students by motivating them on the lessons. It is notable that she regarded herself as a source of knowledge and thought that she can transfer her knowledge to students in a quiet environment by having them take notes. **Hakan** thought that science education is necessary because it includes knowledge about life. He pointed out that if it could be related to daily life, students' interests on science would increase but he did not consider himself as competent in this sense. **Ceren** remarked that by way of science lessons, students learn about science, scientific facts, and technology. In her opinion, weekly class hours for this course should be increased in order to reach the desired targets in science education. **Nil** stated that the topics, which are part of students' daily lives, should be emphasized since as an individual, students would need these topics more than the others. All five teachers thought that science education was necessary. They stated that the knowledge gained in this course was usable (beneficial) in daily life, so the issues and topics should be related to daily life.

Table 3.

Participants' Views on Some Aspects of the NOS

Participants Views about "Science"	
Melih	"…I think it is a study to discover the knowledge which will make life easier"
Ela	"…it makes people's life easier, it helps people adapt to their environment, and it provides people to accommodate their environment and the development in their environment so it makes people well-matched with their nature and gives them more comfortable life"
Hakan	"Generally, this is for the benefit of humanity…". I am naming science as knowledge accumulation…". "I think that science is for making people's life more easier"
Ceren	"I think it is exposing the secrets of the universe. Science is searched and then, formed"
Nil	"I regard science as a work area which is more acceptable to make life more easier and make people getting aware of the things in their environment"
Participants Views about "Scientific knowledge"	
Melih	"For knowledge to be scientific, it should be tested several times and the results of the tests should be close to each other. It should be repeatable and verifiable by experiment…"
Ela	"Scientific knowledge should not be very limited. It should address to everyone in some ways. It should be clear. Not everyone can understand all scientific knowledge. Anyhow, people try to understand what they are interested in."
Hakan	"To me, it is knowledge that people can take use. I think it should be acceptable by everyone. It is retained until it is changed. It is knowledge that can be acceptable by everyone."
Ceren	"It should have certain data. It should have certain data in order to name it as scientific knowledge. If it does not have certain data, we cannot name it as scientific knowledge. The first thing I think is whether we can use it in daily life."
Nil	"It is knowledge that everyone accept. In everywhere, when its conditions are fulfilled, it is true. It must be useful because scientific knowledge should not be harmful."
Participants Views about "Tentativeness of scientific knowledge"	
Melih	"I think knowledge of the existence of gravity cannot change. However, I think, knowledge on atom which was not tried or formed not by trying can change."
Ela	"It can be changed. Some things, we know as true, can change. I said shortly before in atom theory. When we say that it is certain and it cannot change, it will be wrong. However, some things are certain, of course. As far as I know, hypothesis is the first phase, theory is more developed and law has certainty."
Hakan	"After something is called law, changeability of it is very hard, I think. However, change can be in theories. I do not suppose the changeability of something named as law."
Ceren	"Scientific knowledge can be developed. It cannot change but it can be developed. To me laws do not change. Laws are certain. Theory is not proven yet. But, law is proven and exact."
Nil	The things we learn today may be wrong after centuries because science changes day by day and people can find new things. In the future we will learn that the things we learn now are wrong or their causes are different. Law is certainly proven and I think it has no part that will change. It will not change. Law is proven definitely and I think it does not have any part changeable. It cannot change."
Participants Views about "Scientific method"	
Melih	"Curiosity comes first. After curiosity, our thoughts about the topic comes, and then, trying comes and lastly making it law comes, according to my point of view. I think, these steps form scientific method."
Ela	"I think there is certainly a way in starting studies and in the process of studies but some things come into existence randomly."
Hakan	"Steps of the scientific method… These are a research question or the steps starting with curiosity, forming a hypothesis and theory, and ending with scientific laws."
Ceren	"Scientific method is an experiment. Without doing, it cannot be reached any data."
Nil	"We teach children that there is a scientific method. We teach, for example, firstly, one should form a hypothesis. Then, data are gathered and a plan is made."

Teachers' preferred instructional methods and techniques

The classroom observations revealed that all teachers prefer the traditional teacher-centered methods and techniques. They generally use lecture and question-answer techniques in lessons. Besides, if there is a hands-on activity in the textbook or workbook and if the teachers' book requires it be done, then teachers give it as homework. During eight weeks of observation, **Nil** never used the school's science lab. **Melih, Ela** and **Ceren** used their labs just a few times. Also, teachers used the lab hours for demonstrations and not for having the students do some hands-on activities. Hence it was again teacher centered. Unlike other teachers, **Hakan** did all of his lessons in the lab. He divided his students into heterogenic groups of four or five. Each group sat together in the lab. Every week a different group did the activities or experiments and supplied any materials needed. Here, we observed that the students in other groups did not look as interested and thus they usually talked among themselves while a group was demonstrating an experiment.

Assessments

We observed that all five teachers do three types of assessments: written exams (three times as required by the Ministry), classroom performance assignments, and project assignments. The written exams contained questions about the textbook units covered. They typically included 15-20 questions to be answered in one class hour (40 minutes). They were seen as the most important type of assessment to determine students' achievement. In scoring the classroom performance assignments' teachers took into account if students were well prepared and organized, and how well they answered their peers' questions. Lastly, the project assignments were given at the beginning of each semester. Teachers expected their students to research a topic during the semester and prepare and bring a portfolio or another type of written document on the topic at the end of the semester. The term project scoring included "submitting on time" and "being tidy" as the most important rubric items as compared to how the project was done or how it helped the student learn and develop.

Participants' inclusion and evaluation of NOS in the classroom

Melih indicated in the interviews that he was including his views on NOS in his teachings. Nevertheless, he had no planned teaching or assessment strategy for NOS. His rationale was that he did not see NOS as important to spend time on. In addition, he asserted that he did not feel that he was qualified to teach such topics, therefore, other "experts" should teach these topics in separate courses. **Ela** stated that by teaching NOS, the developments about scientific study and the acquirement of scientific knowledge in students' understanding could be provided. She denoted that these topics are interesting for students; they like these issues and feel themselves near to scientific studies. Although she thinks that NOS has very positive effects on her students, she does not give a place for this topic in her lessons. She defines that if students study and submit their research assignments, these assignments are evaluated. According to **Hakan**, the topics such as NOS should be mentioned in their places because these kinds of topics have big impacts on the lives of students. He stated that especially in lessons he focused on the life of scientists, their education and studies. In the process of class observations, it was established that **Hakan** had no teaching or evaluation on the issue of NOS. **Ceren** proposed that she mentioned such topics in their necessary places in accordance with the content of the topic because in her perspective, these are very effective to get students' interest but it was seen in class observations that she does not have such an application. Although **Nil** indicated like other teachers that teaching of NOS is very important, she does not have a planned teaching in her lessons.

Results and Discussion

From the data and findings presented above we generated several assertions as follows:

Assertion 1: *Science teachers have traditional views about NOS.*

This assertion is rooted in the findings presented in Table 2 and Table 3. The VOSTS results indicate that, teachers held naïve and plausible views on many dimensions of NOS. This is consistent with the literature on NOS in Turkey related to in-service and preservice science teachers (Dogan & Abd-El-Khalick, 2008; Doğan, Çakıroğlu, Çavuş, Bilican, & Arslan, 2011; Tasar, 2006; Yakmaci, 1998; Yalvac & Crawford, 2002).

Although VOSTS results indicate that teachers held realistic views along some dimensions of NOS, we were able to infer by the help of the qualitative data that they actually had traditional views in these dimensions. For instance, even though the majority (79.7%) of the teachers had realistic views on tentativeness of scientific knowledge as measured by VOSTS, interviews data reveals that all teachers in the collective case study had traditional views according to the classification scheme of Palmquist & Finley (1997), Haidar (1999) and Tsai (2002).

Table 2 shows that teachers held inadequate or positivist views on NOS. The obvious point here is that their views are very different from the NOS understandings that are promoted in several national and international documents. For instance, all of the teachers confuse science with technology. In a similar way, ideas about the existence of a universal scientific method with certain steps and all scientists following this method were shared by all teachers.

All teachers who responded to the VOSTS held traditional views on the tentativeness and nature of scientific knowledge. The idea of the benefits of science is thought to be caused by the confusion of science with technology. Teachers who think that scientific knowledge can change in time also propose that this change occurs by adding new knowledge to the current scientific knowledge. The idea that scientific knowledge changes but scientific laws never change is also common.

When we think why teachers hold these views, the first thing that comes to mind is that both in Turkey and elsewhere science textbooks have included and promoted such views for several years (Aikenhead & Ryan, 1992; Irez, 2009; McComas, 2000). To illustrate, Irez (2009) examined five 10th-grade biology textbooks and found that there are many wrong and inadequate explanations about scientific method and scientific knowledge. All textbooks included the idea of existence of a universal and scientific method since it was mandated by the curriculum. Besides, in these textbooks hypotheses and theories were labeled as tentative but laws were labeled as the end point of science and not subject to change. In our study the five teachers also seemed be influenced by these wrong and inadequate information in the textbooks.

Assertion 2: *Classroom practices of science teachers are mostly traditional.*

All of the teachers in the collective case study think that science is taught by transferring knowledge from the teacher to the student. Teacher activities and assessments vividly show this assertion. In activities, it is always the teacher who is active and not the students. Teachers did not give sufficient opportunities for students to construct their own learning and to communicate with their peers. Such teacher characteristics are in line with traditional teachers' characteristics proposed by Tsai (2002). Behaviors such as transferring knowledge; memorizing formula, definition, scientific fact and keywords; copying what teacher does; passive listening; finding true answer; true calculation are the justifications of this point of view. All teachers in case study have all of these behaviors. Some teachers' applying different teaching methods, giving examples from daily life, letting students to attend sometimes in activities could not carry them into different classification from traditional teaching because even when they gave place to these activities, they always protected their authorities and control over class.

Assertion 3: *The teachers NOS views are not reflected into their classroom practices.*

Although the five teachers held traditional NOS views and exhibited traditional classroom practices, we do not think that there is a direct connection between the two. The teachers tended not to reflect their NOS views onto their classroom practices because they indicated that these topics are not included in the curriculum, that there is no assessment on these topics in nationwide exams. They also indicated that even if they taught such topics, they did not include them in their assessments.

Although all five science teachers had a consensus on the issue that NOS should be included in science teaching, they do not include them in their own practices in a clear and purposeful way. They emphasized that the most important reason for doing so was the curriculum. However, when curriculum documents for the observed teaching unit "the particulate nature of matter" is examined (MNE, 2005), one can see that it includes many aspects of NOS (for the first time in Turkish science curricula for grades 4-8 since 2005). In general, the curriculum promotes the teaching of many aspects of NOS (e.g., tentativeness of scientific knowledge, the place and importance of observations and inferences in forming scientific knowledge, scientists' life stories, and scientific endeavor).

This is similar to the factors defined in previous studies that can prevent or promote inclusion of NOS views in classroom activities. The factors such as pressure of content (Abd-El-Khalick et al., 1998; Duschl & Wright; 1989), control over class and theoretical principles (Abd-El-Khalick et al., 1998), suspicions about students' abilities, theoretical difficulties, teaching experience, not understanding NOS, lacking resources or experience in NOS assessments prevent inclusion of teachers' NOS views in their classroom practices. As the pressure of centralized examinations in Turkey on content knowledge increases, teachers do not spend time on teaching NOS (Irez, 2006).

Previously, Brickhouse (1999) suggested that there existed a relationship between teachers' views on NOS and their class practices. However, the results of the current study contradict with it. Brickhouse (1999) indicated that teachers' views on science affect their teaching methods and educational aims. We observed that, as if, there was a consistence between teachers' classroom practices and their views on NOS. All of the five teachers held mostly traditional views for NOS and their in-class practices. Nevertheless, when the reasons of their classroom practices were examined in detail, we saw that, rather than teachers' NOS views, some other factors were influential regarding teachers' instructional decisions and practices. Among them the high school placement examinations (high stakes exams), the perceived curricula, and the parents' and school administrators' expectations and tendencies can be counted. These results are in parallel with the results proposed by Mellado et al., (1997), Lederman, (1999) and Chun (2000).

Conclusion

In this study, the views of science teachers on NOS and the reflections of these views on classroom practices were examined in a collective multiple-case study. Similar to the previous studies in the literature, we found that teachers held traditional views about several dimensions of NOS. We had the limitation of not being able to video recording the classroom observations. We did not have the opportunity of having a second observer during the observations, either. The case study teachers were not fully cooperating in data gathering and they had some reservations and hesitations for being involved in such a study. If such limitations can be overcome, then we believe that a more complete picture can be taken regarding the relationships for including or not including the NOS views in teaching science.

The current science curriculum is being used since 2005. Naturally, most of the teachers had been using the previous curriculum which did not emphasize teaching NOS. Likewise, test item writers for national exams are not used to such issues either. Currently, there exists confusion regarding NOS understandings and how they should be taught and assessed, if to be assessed at all. Samples of successful teaching and learning episodes may help teachers include them in science teaching as well, as was suggested by Bartholomew, Anderson, & Moeed (2012).

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