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WHAT NOS TEACHING PRACTICES TELL US: A CASE OF TWO SCIENCE TEACHERS

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Abstract. *Translation of nature of science (NOS) views into teaching practice and the development of teachers' NOS teaching are still open to investigation. Therefore, how teachers' translation of NOS understanding into practice occurs and what extend science teachers are able to transform their understanding into explicit reflective NOS instruction have been issues still need to be further exploration. This study explored the impact of intensive nature of science summer workshop on science teachers' views of NOS and their instructional practices. The current study was a case study of two middle school science teachers documenting their NOS views and instructional practice on NOS in the classrooms. Data resources included the VNOS-C; interviews and classroom observations. Participants made substantial improvements in their understandings of the targeted aspects of NOS as a result of their participation in professional development program. The study also showed that two of teachers translated their understanding of NOS in a certain degree into instructional practice.*

Keywords: *in-service teachers, nature of science, professional development program, science education.*

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Introduction

The need for enhancing society as scientifically literate is regarded as a vital goal in many countries. A scientifically literate person is defined by AAAS (1993), as someone who is familiar with the natural world, understands some key concepts of science, be able to think in a scientific way, aware of the interdisciplinary nature of science, appreciates science, mathematics and technology are human enterprise which implies strengths and weaknesses of science, and be able to use scientific knowledge and ways of thinking for personal and social issues. Thus, science education aims to increase scientific literacy which leads to improve in scientifically literate adults in society resulting in improvement of public understanding of science. Driver, Leach, Millar, and Scott (1996, p. 12) suggested that public understanding of science involves three stages:

1. An understanding of some aspects of science content: It includes understanding of facts, laws, theories which are consisting of scientific knowledge.
2. An understanding of the scientific approach to enquiry: This aspect of science understanding involves ability to define scientific study, distinguish science from non-science. Moreover, this aspect of science understanding recognizes the role of theoretical and conceptual ideas in framing any empirical enquiry and interpreting the outcomes as well as the understanding of empirical enquiry procedures.
3. An understanding of science as a social enterprise: It refers to understanding of science in society and society in science. It is related with knowledge about

science rather than natural world. It involves understanding of the social organization of science, its mechanism for checking, receiving, and validating knowledge and it also includes recognizing of influence of society and values on scientists' choices and interpretations.

Understanding the nature of science (NOS) is stated to be an indispensable part of scientific literacy (Abd-El-Khalick & Lederman, 2000). Furthermore, Driver, Leach, Millar, and Scott (1996, p.12) provided some arguments on why the development of appropriate understanding of NOS was essential in science education: Understanding of the NOS is necessary to make sense of science and manage technology in daily life; informed decision making on socio-scientific issues requires appropriate understanding of NOS; appreciation of science as a part of contemporary culture and recognition of the influence of scientific norms on moral commitments demands understanding of NOS. Lastly, they claimed that it facilitates better science subject learning. In the same vein, Ryder et al. (1999) stated that views on nature of scientific knowledge affects development of students' scientific concepts and appropriate understanding of nature of scientific knowledge leads to more informed students' decisions related with science-based issues.

Although there is no agreement on the meaning of NOS, views held by people on nature of science could be interpreted in terms of values and assumptions inherent to development of scientific knowledge (Lederman, 1992). An appropriate understanding of NOS includes recognition of purpose of science as seeking for explanations in natural world, identifying role of science as social institutions and appreciation of interaction between science and culture as well as understanding the nature and status of scientific knowledge (Driver et al., 1996). Expanding on these ideas, science educators have introduced seven agreed characteristics scientific knowledge which are shared and considered non-controversial and accessible to K-12 students. It is tentative (subject to change); it is empirical based (derived from observations of the natural world); it is theory laden (subjectivity of knowledge); it is partly the product of human, imagination, creativity, and inference; and socially and culturally embedded. Additionally, two more aspects related with the functions and relationship between observations and inference, differences between scientific theories and laws (no hierarchical order between theory and law) (Abd-El-Khalick, Bell, & Lederman, 1998; Akerson, Abd-El-Khalick, & Lederman, 2000).

To help students develop appropriate views of NOS, teachers of all grade levels need to have informed views of scientific endeavours. However, previous research have consistently indicated that teachers generally do not have adequate understandings of NOS (e.g. Akerson & Abd-El-Khalick, 2003; Abd-El-Khalick, & Akerson 2004; Abd-El-Khalick, 2005; Irez, 2006, Dogan & Abd-El-Khalick, 2008). It is self-evident that teachers cannot teach what they do not understand, so it is necessary to improve their understandings of NOS. The research investigations attempted to change naïve conceptions on NOS took two approaches-implicit and explicit-reflective approaches. The former refers to understanding of NOS as a learning outcome that could be attained through process of skill instruction, science content course work and doing science (Lederman, 2007). Learning of NOS is a by-product of learners' engagement with science-based activities. Science teachers or educators intending to use implicit approaches assume that NOS could be taught through focusing on science processes or constructivist activities (Abd-El-Khalick & Lederman, 2000). However, explicit reflective approach intentionally draws learners' attention to aspects of NOS through discussions, guided reflection and specific questioning in the context of activities, investigations, and historical examples. By doing reflection as a part of explicit approach students are encouraged to think about how their work illustrates NOS, and how their inquiries are similar to or different from the work of scientists. Therefore, any attempts to foster better understanding of NOS should provide students conceptual tool that are explicit and reflective (Abd-El-Khalick & Lederman, 2000). Recent review of empirical studies on improving science teachers' understanding of NOS concluded that explicit reflective approach was generally more effective in enhancing appropriate conceptions on NOS (Abd-El-Khalick & Lederman, 2000).

Despite science education reform documents and literature emphasizing the importance of NOS instruction, previous researches have shown that the NOS is rarely addressed in an effective manner by the teachers. Teachers' ability to teach NOS is crucial as well as their understanding of NOS for having students with desired understanding of NOS. Thus, teachers need special support, or trainee for teaching NOS as well as developing their NOS views (Hanuscin, Lee, & Akerson, 2011; Ratcliffe, 2008). Some

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of the researchers explored teachers' views and their clasroom instruction about NOS (Abd-El-Khalick & Akerson, 2009; Akerson & Abd-El-Khalick, 2003; Akerson & Hanuscin, 2007). For instance, Akerson and Hanuscin (2007) conducted a case study exploring development of science teachers NOS practice, understanding and their students NOS understanding for 3 years. Teachers attended in explicit-reflective activities in which inquiry and inquiry based instruction emphasized during the study. It was reported that, through NOS workshops, teachers improved their NOS views. Additionally, on-site support, feedback and reflection on teaching was important components to develop their NOS teaching and to enable teachers to emphasis NOS successfully. Another important result from the same study was that improvement in students' NOS views as a result of successful NOS teaching in the classroom. Similar studies reported need for specific support for teachers' ability to teach NOS which included modeling of NOS lessons, tutoring for NOS, and feedback enabling teachers to transfer their understanding into practice. (Brickhouse, 1990; Gallagher, 1991; Akerson, & Abd-El-Khalick, 2003; Akerson & Hanuscin, 2007; Akerson, Hanson, & Cullen, 2007). Other studies have not found that there were no clear cut relationship between teachers' conceptions of NOS and their classroom practice (Lederman & Zeidler, 1987). They indicated that teachers' classroom practice are affected by many other factors such as curriculum, administrative policies etc. with their conception of NOS. Additionally, teachers' internalization of NOS, and their perception of value of NOS, in addition to curriculum, principles, were also reported to influence their preferences to address NOS into their practice (Schwartz, & Lederman, 2002).

Lederman (2007) pointed out that translation of NOS views into teaching practice and development of teachers' NOS teaching are still open to investigation. Therefore how teachers' translation of NOS understanding into practice occur and what extend science teachers able to transform their understanding into explicit reflective NOS instruction, and to what extent they could show explicit and reflective components of NOS instruction have been issues still need to be further exploration. Such perspective would inform science educators' community better on how to design more effective professional development programs. Additionally, it would provide insights for teacher educators on teachers' need and deficiencies while transforming their NOS views into practice. In the light of the literature, the current study purposed to document two experienced middle school science teachers' NOS teaching practice after attending one week intensive explicit reflective NOS summer professional development program.

The specific research questions of this study were as follows:

- How do science teachers' views of NOS change over one week intensive explicit reflective NOS summer professional development program?
- What extent do science teachers translate their NOS views into their instruction?
- What are teachers' perceptions of their NOS teaching?

Methodology of Research

The current study was a case of two teachers' (1F, 1M) understanding and teaching of NOS and their perceived success about teaching NOS. It was interpretive and emergent in nature (Tobin, 2000). Case study allows us in depth exploration and analysis of a phenomenon (Creswell, 2007; Merriam, 2009). Yin (2008) described case study as ".... an empirical inquiry that investigates a contemporary phenomenon within its real life context especially when the boundaries between phenomenon and context are not clearly evident" (p. 18). Therefore, case study design for the present study would let in-depth exploration of NOS understandings of science teachers and translation of that understanding into practice in real life school context (e.g. Abd-El-Khalick & Akerson, 2009; Akerson & Abd-El-Khalick, 2003; Akerson & Volrich, 2006). Consequently, results and discussions parts would be insightful on success and failure of these teachers which would lead development of better professional developments for both in-service and pre-service science teachers. In a similar vein, the current study was a case study of two middle science teachers documenting their NOS views and instructional practice on NOS in the classrooms. Both teachers were currently teaching science in public middle schools (grades 5-8). Turkish middle schools include the compulsory education of children between 10-14 and lasts four years. Damla has 7 years of teaching experience having no master's or PhD degree. Lastly, Mert has almost 3.5 years of teaching experience with a master's degree. Two teachers had science education degree as major and none of them exposed to explicit reflective NOS instruction before. However, they build a robust rationale for teaching NOS after intensive NOS professional development program. These two teachers agreed to the classroom visit by one of the researchers. Additionally, they were also volunteered on interviews, and sharing their teaching artefacts.

Context of the Study

The study was conducted throughout a program included one-week (30 hours) intensive professional development program introducing NOS aspects to middle school science teachers and giving insights on how to teach NOS. All participants were engaged in different NOS activities that explicitly addressing seven target aspects of NOS. Each NOS aspect was introduced to the participants explicitly through activities followed by group discussions providing reflection opportunities for teachers through the activities. The first two activities were related to the definition and function of science. Another activity was related to the functions of and relationship between theory and law. The activities of "an activity for the first day of class" (Choin, 2004), "tricky tracks", "the whole picture" addressed the difference between observation and inference, the empirical, imaginative, tentative nature of scientific knowledge. The activity of "sequencing events" (Collins, 2002) emphasized the all aforementioned aspects of the nature of science in addition to the theory ladenness nature of science. Two more activities were "the aging president" and "young? Old?" target theory-leadenness and social cultural embeddedness of science. "Black–box" activity was also used to enhance participants' understanding of NOS aspects. All these activities are content generic in nature. Detailed descriptions of some of the activities could be found elsewhere (Lederman & Abd-El-Khalick, 1998).

Beside content generic NOS activities, researchers also used two contextualized NOS activities in the program. Many researchers (e.g. Brickhouse, Dagher, Letts, & Shipman, 2000; Clough, 2003; Ryder, Leach, & Driver, 1999; McComas, 2008; Paraskevopolous & Koliopoulos, 2011) stated that the explicit NOS instruction connected to the context of the science content leads to more improvements in understanding of NOS conceptions. The first contextualized NOS activity was drama based activity in the context of electricity topic (Dogan, Cakiroglu, Bilican, & Cavus, 2012, pp. 108-111). In that activity students worked in the groups and each group was given information cards related with Edison's life and his contributions to the science. Each information card included information about different parts of Edison's life and his discoveries, and how he made these discoveries. Participants were required to show their performance based upon their assigned cards in the groups. After each performance, discussion session was started on what they learned, how they related these activity with how scientists worked. Throughout this activity, empirical and creative NOS were targeted. The second contextual activity was related with the topic of fossils (Randak & Kimmel, 1999). In this activity, participants were asked the following questions: What does a palaeontologist do? What is paleontology?, What is a fossil?, What can fossil tell us? Group of participants were given a set of fossil pieces in the envelope and expected to decide whether the fossils belonged to an animal or a plant, drawing possible shape of either animal or plant. Each groups' presentation of possible drawings was followed by a discussion on how scientists made their decisions. Throughout the activity, participants were expected to discuss on empirical, tentative and imaginative and creative NOS. In addition to these, teachers were challenged about teaching NOS throughout discussion opportunities on possible difficulties that they thought they would have while teaching NOS, and their weaknesses and strengths about teaching NOS. These discussion opportunities lead teachers go through their ideas on NOS teaching.

Data Collection

Data were collected by means of open ended questionnaire and classroom observations. To track changes in teachers' NOS views, Views of Nature of Science Questionnaire–Form C (VNOS-C) (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) was administered at the beginning and at the end of the intensive professional development program. It contained 10 open ended questions addressing each

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particular NOS aspect which were (a) what science is, (b) subjective nature of science, (c) tentativeness, (d) role of creativity and imagination in development of scientific knowledge, (e) empirical basis, (f) socio-cultural embeddedness of scientific knowledge. Additionally, two more aspects as the difference and function of (g) theory and law, and (h) observation and inference were taken into account. Follow-up interviews were conducted to ensure validity of the questionnaire. Each classroom instruction was observed during a semester by researchers.Researchers' field notes from classroom visits also reflected teachers' both NOS understanding and NOS instruction in the class. Additionally, interviews were conducted to understand their perceptions of their NOS practice which included their rationale to teach NOS and their relative perception of teaching NOS. Interview questions were prepared by researchers and lasted approximately 25-30 minutes.

Data Analysis

Each participant was represented by anonymous names as Damla and Mert. Data analysis included writing reflective notes in passages, drafting a summary sheet, writing codes, creating patterns and themes, counting for frequency of codes, relating categories and making contrast and comparisons (Miles & Huberman, 1994). For both research questions two researchers independently analyzed the responses and the analysis were compared and contrasted. Any conflict had been resolved and consensus had been established.

While analyzing the responses to VNOS-C questionnaire, each participant was treated as separate case and data from each questionnaire was used to generate in- depth profile of participants' NOS views related with seven aspects of NOS. Coding of the responses resulted in three types of categories as adequate, mix and inadequate understandings of NOS (Lederman et al., 2002). Through this scoring procedure, views were categorized as "*adequate*" referred to fully developed understanding of NOS views, "*mix views*" indicated emerging NOS views and "*inadequate*" indicated misconception held by the participants (Table 1).

Table 1. An example from rubric related to difference between theory and laws used during the analysis.

Theories/Laws Aspects of NOS	
Adequate view	Theories are proposed explanations and laws are observed relationship with non-hierarchical order between them. Detailed explanation and examples are provided.
Inadequate view	Hierarchical relationship. Laws do not change, theories may change.
Mix view	Non-hierarchical relationship between theories and laws and different from each other but laws as more certain than theories. No example is provided.

The data were reviewed and patterns were formulated in terms of teachers' integration of NOS into their practice to document how NOS aspects were reflected in their instruction. The coding was made two folded regarding NOS instruction: if there were any explicit NOS emphasis in the instruction and if so, how they emphasized it in the classroom. The explicit-reflective approach is an integrated approach that has basis in theory and practice. Explicit and reflective (i.e., explicit-reflective) is meant to suggest that both of these components are necessary as well as complementary (Abd-El-Khalick, 2005). To understand their perceptions of teaching NOS, researchers had been through several rounds of category formation, and category refinement.

Results of Research

Results gained from data analysis presented as Case I- Damla and Case II- Mert. Each participant's NOS views, NOS practice and NOS teaching perceptions are described in detail below.

Case I - Damla

NOS views: Analysis of responses to VNOS-C questionnaire revealed that Damla improved her views toward inadequate to mixed on four aspects of NOS namely sociocultural embeddedness, theory and law, observation and inference and subjective NOS. For instance, for socio-cultural embeddedness she recognized science as universal but at the same time affected by social cultural values of the society. She stated: *"…. Science should be universal. It is the scientists' mission to bring up a different perspective to the things. If you have a different perspective other than society, and could interpret differently and make people think, then it means you fulfil your goal as a scientist. Thus, science should be universal and it is universal. However, we need to acknowledge that all scientists are influenced by the society's norms and culture they live in because we are all human beings. Scientific studies could be shaped based on this."*

For theory and law, she was able to define theories as proposed explanations. She was able to explain law by giving examples as an observed relationship. However, she pointed out laws more certain than theories. This misconception was evidenced by the following quote: *"Gravitational force of the earth is a law. Calculations of it, or theories related to it might change but earth has a gravitational force. Objects fall to the ground…. We can develop a theory to explain law…. Theories are used to propose explanations. Laws are more certain."*

For subjectivity, she recognized scientists' different interpretation of the same data by stating: *"While they are doing observation, or evaluating data they could focus on parts that other groups of scientists do not focus or group of scientists could focus on different parts of the data or observation…"*

She remained her ideas on imaginative and creative and empirical NOS same as at the beginning of the intensive NOS professional development program. She kept her views on the role of imagination and creativity in the development of scientific knowledge as mixed and her views on empirical NOS as adequate (Table 2).

Table 2. Damla's NOS views before and after intensive professional development program.

NOS Aspects	Pre-Professional Development Program	Post- Professional Development Program
Tentativeness	Mixed	Adequate
Imagination / Creativity	Mixed	Mixed
Socio Cultural Embeddedness	Inadequate	Mixed
Observation / Inference	Mixed	Adequate
Theories /Laws	Inadequate	Mixed
Empirical Basis	Adequate	Adequate
Subjectivity	Inadequate	Adequate

NOS Teaching: She was observed through five class hours while she was teaching evolution, the buoyancy of liquids and pressure topics. Through her teaching her efforts to emphasize NOS explicitly were detected. She generally used expository teaching method and questioning strategies through her teaching and made NOS emphasis through some examples, activities and questions. Among her adequate views of NOS, she covered subjective, tentative and empirical NOS, (as well as observation versus inference). Most of the time, she was simply "telling" students about the target NOS aspects rather than providing them with experiences to help them develop these idea on their own. For instance, while she was pointing out for subjective NOS, she gave a brief description of what subjectivity in science was. However, she avoided creating discussion, or giving opportunities for students' reflection on subjective NOS:

> Damla: Scientists might not always be objective. They might interpret the results through the lenses of their own ideas and perception
>
> Student: .... If they include their own ideas, they might make mistakes

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> *Damla: " ..... they combine their knowledge with the new one and through that of course their personal background affect that. Remember the evolution theory while some of scientists accept it but some of them do not agree with it."*

She stressed tentative NOS throughout the teaching of topic of pressure. Unlike teaching subjective NOS, while teaching tentativeness she showed efforts to create discussion environment and provided opportunities for students' reflection on their ideas rather than directly lecturing what tentative NOS was. However, her efforts to create discussion on tentativeness did not go beyond asking short- answer questions and she could not keep up NOS discussion. Actually, she made a good start with question *"Think about laws! Do you think these laws could change?"* but she could not extent the students' discussion instead ended up making explanations (lecturing) what tentative NOS was:

> *Damla: We learned laws that Pascal found about pressure. Think about laws ……*
> *Do you think these laws could change?*
> *Student I: Yes, it changes*
> *Student II: Never change*
> *Sudent III: Rules never change*
> *Student IV: Atom models changes as well, thus laws could change*
> *Damla: Yes, this is a good point. Atom models changed. There have been so many different models for Democritus' atom models to Bohr' atom model to until now. All these theories include knowledge about atom but through new investigations, new evidences obtained through observations and inferences, which change the old information and let us get new scientific knowledge.*

Additionally, she gave another example related to daily life in the same content to reinforce the idea of tentative NOS. Similarly, it was lack of student reflection and discussion opportunities too *"I saw it on a newspaper. A substance providing invisibility was produced. That kind of production is so different than we already know now. That kind of studies shows us scientific knowledge might different and changeable."*

Furthermore, it seemed she used NOS related terms such as observation, inference and evidence which indicated she internalized NOS *"All these theories includes knowledge about atom but through new investigations new* ***evidences*** *obtained through* ***observations and inferences****, which change the old information and let us get new scientific knowledge."*

While teaching buoyancy force, they made an inquiry based activity and during the activity, she emphasized empirical NOS. She kept her teaching NOS approach as teacher centered and avoided NOS discussion:

> *"We made some predictions through our experiments, some of the predictions were wrong, some of them were correct, but we decided that after we made experiments. Scientists were working like you their predictions could be wrong as well. They tested that with experiments and make inferences….."*

In general, her NOS teaching was explicit and included efforts to initiate NOS discussion. However, her science instruction was mainly based on teacher centered strategies. This is also true for her NOS instruction. Although her efforts included NOS specific questions, she barely kept up NOS discussions and gave opportunities for students' reflection on how science works. Since explicit and reflective components of instruction are complementary, her NOS teaching was lack of exemplary instruction regarding NOS and labeled as lack of explicit reflective component.

NOS teaching perceptions: When she was asked about the difficulties she faced while teaching NOS, she claimed that students' grade level and comprehension level, and motivation were the obstacles influencing her NOS instruction:

> "The class you observed was a kind of tough class because it was crowded and students' comprehension levels were not appropriate. I think my NOS teaching would be better with seventh or sixth grades."

She also stated that teaching empirical NOS could be easy by addressing observations and experiments. However, she found complicated teaching of theory and law because she still might have held her previous conceptions about it, and she lacked of enough examples related to theory and law:

> *"Teaching evidences based on observations and experiments, hypothesizing and validating these through experiments were easier. However, teaching theories and laws were complicated. I felt I was using my previous knowledge/misconceptions while I was teaching… giving examples about theories and laws were hard…."*

Additionally, she also pointed out the importance of teaching NOS in order to develop positive attitudes towards science among students and lead them to be more willing to do science *"… They would have a broader perspective… they would realize science develops. That awareness would bring the idea that they would change, develop and reflect that change into their life …"*

In order to integrate NOS into her teaching, she mentioned that she used science textbooks as a source:

> *"In our textbook, I saw the inclusion of NOS. Especially for seventh grade in atoms topic, and for the topic of force, it provides some information about science, what science is and tentativeness of scientific knowledge… I realized that NOS is there when I read…"*

Summary of Damla's views of NOS, NOS understanding and NOS teaching perceptions are given below (Table 3).

Table 3. Summary of Damla's NOS understanding, NOS instruction and NOS teaching perception.

NOS Aspects	NOS understanding	NOS Integration	NOS teaching perception
Subjective NOS	Adequate	Lecturing Lack of explicit- reflective	Obstacles for teaching NOS: *Students' comprehension level *Students' motivation *Her lack of understanding
Empirical NOS	Adequate	Inquiry based activity for teaching NOS Lack explicit reflective NOS instruction	
Tentative NOS	Adequate	Efforts to create NOS Discussion environment NOS questions Explicit-reflective Opportunities Daily life example to teach NOS Use of NOS language	Motivation for teaching NOS: *Utilizing students' interest/attitude/motivation for science

Case II - Mert

NOS views: When we analyzed participants' NOS views, we found that he developed his understanding on subjective, tentative, socio-cultural embeddedness of the NOS and observation and inference. For subjectivity, prior to intensive professional development program he did not recognize the role of scientists' background, preconceptions and assumptions on development of scientific knowledge. However, after professional development program, he realized that scientists made different inferences and used of different scientific methods. Additionally, he also held the view that scientists' different explanations were due to their lack of evidence. In response to the question related to extinction of dinosaurs he stated the different explanations of scientists because of lack of precise evidences but he recognized the different interpretations of scientists owing to different methods to reach scientific knowledge: *"…here scientists made some assumptions and inferences. Because they don't have enough evidence… that shows that scientists might infer differently even they observe the same thing. That is, reaching the same conclusions via different methods. That means scientists don't have to use the same method to make conclusions. They could use different methods..."*

For tentative NOS, he shifted his mixed views to the adequate one. At the end of the intensive workshop, he recognized tentative science due to uncertain theories, but at the end, he identified tentativeness due to different interpretations of different scientists and technological improvements. He said that: *"As time progresses with the development of technology and resources and society needs, and need for different perceptions required scientist develop scientific knowledge they gained once. Developments in scientific knowledge are the requirement for development and sustainability of science."* For observation and inference, although he did not mention inference directly, he implied that scientists made conclusions based on observations and experiments in his responses at the end, he recognized inferential NOS at the end of the intensive professional development program.

> *"As we all know science is based on observations. Scientists make inferences based on their observations...For atom theory, atom's nucleus and spinning particles- proton and neutron around it were not observed directly... Experiments indicated that structure...."*

For socio cultural embeddedness, he shifted his views from mixed to adequate one. That is, he was able to recognize how social cultural values influenced the science and he also extended his explanations by giving examples: *"During the cold war period, Russian or American scientists shifted their work towards defence, weapon technologies and space studies. For space research Russia and USA competed with each other... Since there was a global and societal competition between these two countries, scientists canalized their work toward these areas."*

He remained his views on empirical and creative NOS as adequate (Table 4).

Table 4. Summary of Mert's views on NOS aspects.

NOS Aspects	Pre-Professional Development Program	Post-Professional Development Program
Tentativeness	Mixed	Adequate
Imagination / Creativity	Adequate	Adequate
Socio Cultural Embeddedness	Mixed	Adequate
Observation / Inference	Mixed	Adequate
Theories /Laws	Inadequate	Inadequate
Empirical Basis	Adequate	Adequate
Subjectivity	Inadequate	Mixed

NOS practice: He was observed through five class hours through the science topics of buoyancy force, pressure and chemical bonds. Among the adequate ideas he had he stressed subjective, tentative, empirical, and creative NOS in his instruction. He also addressed the nature of theory and law. Analysis of field notes revealed his explicit efforts to emphasize NOS in his instruction. He mostly used teacher-centered instructional strategies enriched with NOS specific questions and examples from history of science (HOS) to point out NOS explicitly. However, his manner for teaching NOS was mostly included less reflective component, and mostly based on giving definitions. That is, he was lack of student-centered instructional strategies such as inquiry based instructional activities stressing NOS explicitly. During teaching subjectivity, similar with the previous case although his views were reported to be mixed, it was observed that he had adequate understanding of subjective NOS throughout his teaching recognizing scientists' different explanations due to their background, and culture. He addressed subjective NOS twice among the five classes visits. He emphasized subjectivity explicitly in the context of teaching of evolution. He stressed it explicitly, and used questions to start NOS discussion. Here, he encouraged students to think about science and how science works through Lamarck's and Darwin's different views about evolution. However, he preferred to give definition of subjectivity directly at the end without giving any space for students to reflect their own views. The following excerpt shows how he addressed subjective NOS in his teaching:

Mert: ... Why did Darwin and Lamarck make different explanations on the same theory?
Student: Maybe because they think differently.
Mert: Why?
Student: Because they conducted researches on different issues.
……………………………………………………..
Mert: Why did all of you see different things when you looked at me?
Student: Because we are different.
Mert: Why are you different?
Student: We are thinking differently.
Student: Our viewpoints are different.

Mert: You're right, our point of views are different, because we are thinking differently. This is because of the fact that our prior knowledge is different and you grew up in different cultures. Therefore, your viewpoints are different. Scientists also think in this way. Their prior knowledge is different as well. Therefore, they sometimes cannot be objective.

In the same context, he also pointed out the nature of theory and law. However, during his teaching it was seen that he held misconception about theories and laws. He explained laws as certain proved knowledge and could not be refuted yet, whereas theories are not certain as laws. He reflected this misconception explicitly through his teaching:

Mert: What do you think about the theories and laws? Do they change, according to you?
Student 1: I think they don't change. Gravity law is the same everywhere. Laws have been proved.
Student 2: Maybe theories change. For example, the theory of the atom has changed. But laws are more valid than unaltered theories, they have been proved.
Mert: What are the theory and law?
Student 1: Law comes right after the theory and it is a more certain knowledge.
Student 2: Yes. Law does not change.
Mert: A knowledge, which its reliability and correctness has been proved and it cannot be debuted, called as "law". As you remember, we covered the issue of "Mendel Laws" in the last unit.
Mert: For example, there are theories. As one of your friends said before, theories can be thought as a pre-stage of the laws, but actually they are not. We can give the "Evolution Theory" as an example. Theories are the true and accurate knowledge just as laws but they're more tend to change

He used a reading script from history of science to teach tentativeness. While teaching buoyancy, he asked students to read a script about Pascal's life. Then he started a discussion about the tentative nature of scientific knowledge:

Mert: You can make observations, use your old knowledge and also you can create scientific works and knowledge by using your imagination and through your own interpretation and inference. Our real issue was the changeability of the scientific knowledge. For example, when we were in middle school, the atom was the smallest part of the matter. But now, we know that it can be divided into pieces. What has changed between this time period?
Student: The technology has been changed.
Student: The opportunities that we have changed. And therefore our ability to make observation has changed.
Student: Our viewpoints have changed.

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Student: For example, one of the planets has changed. Before, there were 9 planets.
Mert: Actually it is a change of scientific knowledge in present time, which you have witnessed. What was the thing that changed? Pluton continues to be a planet as a "dwarf planet" because of the fact that it does not conform with the new definition of the "planet".

Here, it was found that he reflected his adequate understanding on tentative NOS into his practice explicitly. Similar with his subjective NOS instruction, he started with questions to create NOS discussion. He also gave more space for students' reflection by asking more NOS questions and providing more time for students to think about tentativeness of scientific knowledge. He let students tell their ideas and give examples from science indicating the tentative nature of scientific knowledge. Additionally, his usage of NOS friendly language was also notable. Through the discourse with students, he used terms like *observation* and *inference* more compared with his observed previous lessons.

Although he attempted to address the tentative NOS by promoting discussion in the classroom, he was simply "telling" students about the imaginative and creative NOS rather than providing them with experiences to help them develop this idea on their own. The following excerpt shows how Mert addressed the imaginative and creative NOS:

Mert: You can make observations, use your old knowledge and also you can create scientific works and knowledge by using your imagination and through your own interpretation and inference……"

Distinctively from his other observed lessons, he used an inquiry based teaching strategy while teaching the empirical NOS that he had adequate views of these aspects. He pointed out these issues while he was teaching pressure topic. To facilitate students' understanding of the empirical NOS, he conducted the three-hole bottle activity. The following excerpt shows how he addressed the empirical NOS in his teaching:

Mert: What we will observe after I open the lead of the bottle?
Student 1: there will be water leak from the holes.
Student 2: water leaks only from the hole at the top.
Student 3: No, the most leaks will be from the hole at the bottom like in balloon experiment.
Mert: "Good…Your friend made an inference based on his previous observations like scientists. Please don't forget scientific information is gained by doing experiments. Let's open the lead and see what happens?"

Although he started his explicit NOS instruction with an inquiry based activity, he was lack of keeping up NOS discussion. Instead, he directly told students how the activity was related to how science works. In general, although his NOS instruction was explicit and also he showed efforts to create NOS discussions by asking NOS specific questions, he gave less space to students to reflect their own ideas on science through written or oral expressions.

NOS teaching perceptions: He acknowledged students' misconceptions and cookbook style of science textbooks as the drawbacks in his NOS teaching.

"*NOS is an unfamiliar concept for our students. Before we used to have books which had a cookbook style, but we changed our perspective with NOS. At first we had difficulties due to students' misconceptions....*"

Similar to Damla he also acknowledged his difficulties in addressing the nature of theory and law by stating the reason of both students' comprehension levels and his lack of understanding of this aspect:

"I had difficulties while teaching theories and laws. It was difficult to teach What is a theory, What is a law, What is the difference between them? Students have generally mixed up these terms. Actually I also had difficulties in fully understanding them due to the misconceptions I had about these concepts."

Regarding his NOS integration into his teaching, he stated that even he had some concerns at first about teaching it. However, he stated that while he started teaching NOS, he noticed students' motivation increased: "*"Initially I had concerns regarding how to teach NOS and students' reactions. However, when I started to teach it with help of knowledge I gained from NOS workshop, students' interest about how science works increased....then I started to focus on what science is, how it works, and how NOS concepts are related to each other...."*

Summary of Mert's views of NOS, NOS understanding and NOS teaching perceptions are given below (Table 5).

Table 5. Summary of Mert's NOS understanding, NOS instruction and nos teaching perception.

NOS aspects	NOS understanding	NOS integration	NOS teaching Perception
Subjective	Mixed	NOS specific questions Lack explicit reflective NOS instruction	Obstacles for teaching NOS: *Students' misconceptions *Students' comprehension level *His lack of NOS understanding *Cookbook style textbooks
Empirical	Adequate	Use of an inquiry based activity Less space for students' NOS discussion Lack Explicit of reflective NOS instruction	
Tentative	Adequate	HOS based example NOS questions Efforts to create NOS discussion environment Explicit-reflective NOS instruction	Motivation for teaching NOS: *Utilizing students' motivation for teaching NOS

Discussion

The current study is a case study of two middle school science teachers documenting their NOS views and instructional practice on NOS in the classrooms after attending one week intensive explicit reflective NOS summer professional development program. These teachers were ascribed to the target aspects of the NOS using explicit reflective NOS instruction and given insights on how to teach NOS during one-week, all-day, intensive professional development program. Consistent with previous studies, the present study revealed that both participants improved their views on tentative, subjective NOS, socio cultural embeddedness of scientific knowledge and role and function of observation and inference. That is, explicit reflective intensive NOS professional development program was effective and provided opportunities for participants to revise and refine their NOS views (Hanuscin, Lee, & Akerson, 2011; Abd-El-Khalick, 2001; Abd-El-Khalick & Lederman, 2000). Distinctively, both participants had adequate understanding of the empirical NOS and inadequate understanding of theories and laws both at initial and at the end of the program. Both participants had a similar education background in which they exposed to misconceptions related to hierarchical order between theory and laws in science textbooks (McComas, 2008; Irez, 2009). Consistent with these findings, Irez (2009) reported that Turkish biology textbook fails to emphasize fundamental aspects of the NOS. Additionally, it was found that Turkish science textbooks revealed science as a collection of facts rather than a dynamic process producing explanations about nature. However, for empirical basis, mostly they engaged in inquiry activities even if they were mostly cookbook style textbook in which they test ideas, do experiments and gather data. Thus, as Bell (2004, pp. 427-446) stated, their understanding of empirical NOS might be due to these experiences they engaged in during their education.

Although previous research reported that adequate understanding of NOS does not guarantee translation of NOS views (Abd-El-Khalick & Lederman, 2000), result of the current study revealed participant teachers' efforts for emphasizing NOS explicitly. One of the other reasons why two of the teachers

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have chosen to integrate their understanding of NOS through instruction might be that they have at least some level of internalization of importance of teaching NOS as a learning outcome. They both stated robust rationales to teach NOS as a motivating factor for science learning prior to classroom visits (Abd-El-Khalick, Bell, & Lederman, 1998; Akerson, & Abd-El-Khalick, 2003; Lederman, 2007). Another factor motivating them to address NOS explicitly and reflectively might be their sense of self-efficacy for teaching NOS. Self-efficacy for teaching NOS has been reported to be important motivation influcing teaching practice (Bilican & Cakiroglu, 2012). Structure of NOS professional development program that teachers attended might have been contributed to development of their self-efficacy for teaching NOS which resulted in efforts to teach NOS in their classroom. Despite their detected intentions to teach NOS explicitly, it was found that their instruction was mostly based on teacher centered and lack of reflective component of NOS instruction. Explicit and reflective components are complementary for an exemplary NOS instruction (Abd-El-Khalick, 2005), but teachers' NOS instruction could not achieved fully explicit reflective NOS instruction. However, reflective component of NOS instruction was reported to be effective means of NOS instruction (Yacoubian & BouJaoude, 2010). Thus, participants need to have variety of examples, specific instructional activities, feedback and support to be able to teach NOS both reflectively and explicitly (Abd-El-Khalick & Lederman, 2000; Akerson & Abd-El-Khalick, 2003; Lederman, 2007; Akerson & Hanuscin, 2007). Although participants' tendency to teach NOS through teacher-centered teaching strategies, one of the participants attempted to address the tentative NOS in a more reflective manner. That is, he used inquiry based instructional activity, and used more NOS related questions to initiate discussion for addressing tentativeness. This might be due to reason that tentative NOS were emphasized throughout the contextualized and de-contextualized activities. Contextualized activities were reported to be more effective in facilitating NOS views (Seung, Bryan & Butler, 2009). Consequently, a blend of these two strategies might have a deeper effect on participants' views. Additionally, union of these contexts might better provide participants with knowledge of instructional strategies to teach tentative NOS (Seung, Bryan, & Butler, 2009; Bell, Matkins & Gansneder, 2011). Therefore, the findings of the study suggested that NOS activities providing variety of learning contexts might be more effective in improving teachers' NOS views as well their ability to teach NOS. Regarding improvement of NOS teaching , variety of the contexts provided teachers with selection of examples and more instructional practices of embedding NOS into science content in an explicit and reflective manner which result in their students' better understanding of NOS (Akerson, Cullen & Hanson, 2009; Akerson, Hanuscin & Lee, 2011).

Futhermore, both of the participant teachers faced difficulties in teaching nature of theory and laws due to their misconceptions and students comprehension levels which brought the importance of teachers' conceptions in their ability to teach NOS (Abd-El-Khalick,& Akerson, 2009; Seung, Bryan & Butler, 2009; Lotter, Singer & Godley, 2009). Analysis of field notes revealed that one of the participants emphasized theory and law in his instruction and he transferred his misconception explicitly to the students. In that sense, teachers role in having students with desired understanding of NOS had been emerged repeatedly (Abd-El-Khalick, & Akerson, 2009; Seung, Bryan, & Butler, 2009; Lotter, Singer, & Godley, 2009). Another important finding was that one of the participants took attention to the textbook as a resource for NOS teaching. Her alert to textbook as a NOS teaching resource is important and might be a first step of ability to adapt curricular material to meet instructional goals and students' needs while teaching NOS explicitly and reflectively as well (Davis, 2003; Lederman, 1992).

Conclusions

This study explored the impact of intensive nature of science summer workshop on science teachers' views of NOS and their classroom practices. We found that participants made substantial improvements in their understandings of the targeted aspects of NOS. This study also showed that two participating teachers translated their understanding of NOS in certain degree into instructional practice as a result of their participation in professional development program. As a part of professional program we used explicit–reflective NOS instruction with the idea that we specifically teach teachers the target NOS elements to encourage them to explore their understandings and increase their content knowledge of the

NOS. Hence, two science teachers' efforts were appreciated when taken into consideration that their first time to hear "nature of science" through the one week intensive professional development program, and they had no chance to think and reflect about how science works before.

In this program, the content generic activities, discussion and reflection on these activities provided experiences for the participant teachers to strengthen their understanding of NOS and gave opportunity reflect their understanding through their practice. However, it may be difficult to improve and reflect on their NOS views and have appropriate pedagogical practice at the same time. Therefore, for more robust explicit nature of science instruction, all these teachers need to see examples of how NOS could be reflected through their practice in classes.

Due to the importance of reflective component of NOS teaching, professional development programs, and science education programs need to provide opportunities for both in-service and pre-service science teachers reflect on their teaching practices. Thus, both pre-service and in-service teachers need to see models of how to be reflective and explicit in NOS instruction. Accordingly, to improve their NOS teaching practice, they might need successful modeled NOS lessons, and opportunities to design and teach NOS lessons in an explicit reflective manner followed by reflection opportunities on these lessons. However, current study had some limitations such as duration of NOS professional development program that teachers attended. Longitudinal studies including continuous support, feedback on teaching, and reflection opportunities regarding NOS practice of teachers would inform better science education community on teachers' NOS understandings and NOS teaching practices. In addition to these, NOS teaching packages, including variety of resources and modeled lessons for NOS teaching would encourage science teachers to address NOS explicitly in their instructional practice.

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