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Abstract: *The aim of this study was to investigate the effect of an activity-based explicit nature of science (NOS) instruction undertaken in the context of a "Science, Technology and Society" course on the prospective science teachers' (PSTs') understandings of NOS. In this course, social science based inquiry activities were used to as a context to lead reflection and explicit discussions and project based learning approach (PBL) was used to model an active student centred NOS teaching and learning. Participants were 36 senior PSTs. An adopted form of VNOS questionnaire along with semi-structured interviews was used to assess participants' conceptions before and after the instruction. Data were analysed both qualitatively and quantitatively. It was found that the majority of PSTs hold naïve or mixed views about most aspects of NOS at the beginning of the instruction. The post assessment indicated a substantial development in the participants' conceptions about many aspects of science; however, little change took place for either conceptions related to the social and cultural influences on science or creativity and imagination in science.*

Introduction

Helping people to be scientifically literate has been a central goal of science education reforms in many countries such as United State of America, Canada as well as in Turkey (American Association for the Advancement of Science [AAAS], 1993; Deboer, 1991; Ministry of Education [MOE], 2007; Turkish Ministry of National Education [MEB], 2005; National Research Council [NRC], 1996). With respect of this goal these countries have tried to make core changes in their science curricula and teacher training programs in recent decades to prepare scientifically literate people. Understanding the nature of science (NOS) is thought as a key concept of scientific literacy (DeBoer, 2000; Kimball, 1967-1968; Lederman, Abd-El-Khalick, Bell, & Schwardz, 2002). As teachers' understandings about NOS and science teaching can influence their approach to science teaching and consequently their students' understandings, since the early 1960s, there has been a major effort to help teachers and students to develop adequate conceptions about NOS (Brickhouse, 1990; Driver, Leach, Millar, & Scott, 1996; Gallagher, 1991; Hodson, 1993; Palmquist & Finley, 1997; Shapiro, 1996; Tairab, 2001).

However, several studies (Abd-El-Khalick, Bell, & Lederman, 1998; Hodson, 1993; Lederman & Zeidler, 1987; Lederman, 1999; Mellado, 1997) identify relationships among teachers' conceptions about NOS; their instructional activities in real environments and their students' conceptions about NOS, have indicated that there is not a linear relationship among these variables. (AAAS, 1993; Abd-El-Khalick & Lederman, 2000a; Gallagher, 1991; Lederman, 1999; NRC, 1996; Schwartz, Lederman, & Crawford, 2004).

Research shows that most teachers and students have misconceptions about NOS (Abd-El-Khalick & Lederman, 2000a; Abell & Smith, 1994; Bloom, 1989; Craven, Hand, & Prain, 2002; Haidar, 1999; Kimball, 1967-1968; Lederman, 1992; Moss, Abrams, & Robb, 2001; Murcia & Schibeci, 1999). The naïve conceptions or inability to transfer informed conceptions about NOS is linked to the fact that most prospective teachers have not had opportunities to engage in instruction during their teacher training, where NOS is explicitly addressed as science content and scientific inquiry is used as a pedagogical approach to teach this content (Shapiro, 1996; Windschitl, 2003).

Lederman (1999) encourages science teacher educators to extend their efforts beyond the development of an understanding about NOS, by addressing the translation of NOS to classroom practice. In order to help teachers develop informed understandings about NOS and effectively transfer their informed understandings to their instruction, more effective approaches are required to help teachers to gain teaching strategies for science teacher training programs (Abd-El-Khalick & Lederman, 2000a; Eichinger, Abell, & Dagher, 1997; Rudolph, 2000).

In attempts to help teachers to develop NOS understandings, it was found that pre-service science teachers complain that NOS instructions and activities they participate in do not help them to use these activities in their professional science teaching (Abd-El-Khalick et al., 1998; Bell, Blair, Crawford, & Lederman, 2003). In addition, when teachers have been asked, how do your students learn best, the majority of them responded that their students learned the same way their teachers learned (Simmons et al., 1999). The most influential factors that influence student understandings are learning activities and instructional behaviours modelled in instruction (Mellado, 1997). To help teachers develop understandings about NOS, teachers should contextualize their NOS understandings in learning environment, in which they see connections between their NOS understandings, teaching science, and classroom practice. The context, in which they were taught science, and the context, which they are expected to teach science, should have similarities (Abd-El-Khalick, 2001; Abd-El-Khalick & Lederman, 2000b; Hodson, 1996; Mellado, 1997).

Historically, several approaches, especially "implicit" and "explicit", have been used to develop science teachers' conceptions about NOS (Abd-El-Khalick & Lederman 2000a). These studies focus on designing, implementing, and testing curricula aimed at developing accurate conceptions of NOS. The implicit approach refers to the teaching of history and philosophy of science courses (Klopfer, 1969; Lin & Chen, 2002; Lin, 1998) or science methods courses (Barufaldi & Bethel, 1977; Sandoval & Morrison, 2003) without including any reflection on the activities and experiences, which students and instructors are involved in. In contrast to the implicit approach, in an explicit approach instructors use elements from history and philosophy of science or scientific inquiry to reflect on experiences or activities in regard of NOS (Abd-El-Khalick, 20001; Akerson, Abd-El-Khalick &Lederman, 2000; Khishfe & Abd-El-Khalick, 2002). Evidence has shown that explicit approach is more effective than implicit approach to help teachers to develop understanding about NOS (Abd-El-Khalick, 2001;Abd-El-Khalick & Lederman, 2000b, Akerson et al., 2000; Khishfe & Abd-El-Khalick, 2002).

Advocates of explicit approach suggest that the most effective way to learn about science is to experience activities, which include explicit discussion on the aspect of scientific endeavor. Thus, many have argued that the specific aspects of scientific enterprise that characterize NOS should be addressed specifically in instruction via specific activities, which enable students to actively construct their own knowledge of NOS. (Abell & Smith, 1994; Clough & Clark, 1994; Clough, 1997; Gess-Newsome, 2002; Hodson, 1996; Lederman & Lederman, 2004; Lederman & Zeidler, 1987; Matkins, Bell, Irving, & McNall, 2002; Meichtry, 1999; Ryder & Leach, 1999; Ryder, Leach, & Driver, 1999; Shapiro, 1996). So, more authentic learning experiences have been suggested to help students to develop their own NOS conceptions (Abd-El-Khalick & Lederman, 2000a).

The most common form of authentic inquiry approach incorporated with reflection, which represents authentic scientific endeavour, is project-based science (PBS). The essential aspect of PBS is the guided reflection. In this approach, learning is organized around projects. Students can decide how to approach a problem and what activities to pursue. They gather information from variety of sources and synthesize, analyse and derive knowledge from it. Their learning is inherently valuable because it is connected to some real thing and involves adult skills such as collaboration and reflection. In the end, students demonstrate their newly acquired knowledge and are judged by how much they have learned and how well they communicate it. Throughout this process, the teacher's role is to guide and advice rather than direct and manage student's work (Fleming, 2000; Solomon, 2003; Thomas, 2000). It is assumed that such an approach can help teachers to appreciate that scientific endeavour is a complex, socially constructed activity and help them to develop NOS understanding.

The PBS approach is the outcome of understating that knowledge cannot be transferred from one person to another and it must be constructed by the learners through actively participating in authentic learning environments (Arends, 2007; Bodner, 1986; Hodson, 1993; Marx, Blumenfeld, Krajcik, & Soloway, 1997; NRC, 1996). But, it is thought that there is not enough emphasis given on authentic learning to help teachers develop conceptions about NOS (Meichtry, 1999). It is also believed that NOS has been relegated to instructions, where they typically presented out of context, which was not convenient to help teachers to gain NOS understandings (Brickhouse, 1990; Hodson, 1993; Hodson, 1996; Lederman, 1997; Shapiro, 1996).

In this study, because teachers mostly confront concepts and applications of social science both during their training and profession, prospective science teachers (PSTs) were engaged in social science based activities. Through these activities, prospective teachers were mostly asked to investigate students' and teachers' conceptions about NOS, science teaching and learning.

The aim of this study was to investigate the effect of an activity-based explicit nature of science (NOS) instruction undertaken in the context of a "Science, Technology and Society" course on the Turkish prospective elementary science teachers' understandings of NOS. The following research questions guided this study:

What kinds of conceptions about NOS do prospective elementary science teachers have at the beginning of instruction?

Does the course, which pursues an explicit activity based approach, influence prospective elementary science teachers' conceptions about NOS?

Method

This study has a qualitative nature (Bogdan & Biklen, 2003). This required to focus on the meanings that PSTs ascribed to the NOS aspects in their pre and post-written and oral responses to the questionnaire and interview respectively. Sample of the study was chosen based on convenient sampling method. Data were collected using convenient sampling method at the beginning and end of instruction by an open-ended questionnaire and interview. One of the restriction of this sample method is that its results cannot be generalized to the expanded population, results are only restricted with its sample (McMillan & Schumacher, 2001). The author served as the primary researcher, the participant observer in instruction, and took responsibility for data collection, analysis and interpretation. For data analysis, both inductive and deductive techniques of content analysis, which is qualitative, and descriptive quantitative analysis were used.

Participants

The sample of this study was 36 senior PSTs who were seeking a teacher certificate in an elementary science-teaching program in a Turkish college. They were enrolled in a compulsory Science-Technology-Society (STS) course, which was three credit hours per week, during this study for one semester that spanned 14 weeks. All of them had a general and similar science background. PSTs are chosen to teacher training programs based the scores they got from Turkish National University Entrance Examinations. They are required to take general science courses (Chemistry, Biology and Physics), pedagogical courses and elective courses for teacher certification during their teacher training.

Data Collection

In this study, Views on the Nature of Science Questionnaires (VNOS-B, C) (Abd-El-Khalick & Lederman, 2000b) were used to have a modified questionnaire to assess PSTs conceptions. Three more questions, which are item 6, item 9, and item10, were added to original items from VNOS questionaries. Item 6 is related to the tentative characteristic of scientific knowledge. Item 9 was asked to investigate participants’ conceptions about the inventive characteristic of scientific knowledge. Item 10 investigated understandings about technology and the interactions between science and technology. However, the original VNOS questionnaires include items, which are related to different aspects of the tentativeness and creativity in science (Lederman, Wade, & Bell, 1998). There was not any direct item asked about the tentativeness of both scientific theories and laws, and inventive aspect of science. Furthermore, there is no item in original VNOS to assess conceptions about technology, or the relationship between science and technology, as well as their functions. The modified VNOS questionnaire was presented in Appendix A. Table 1, which shows directly related NOS aspects and items on the questionnaire in this study, presented in the following:

NOS Aspects	Related İtems Number
Science	1
Scientific Theories and Laws	3
Social and Cultural Influences on Science	4
Creativity and Imagination in Science	5, 6
Theory-laden	7
Differences Between Observation and Inference	8
Tentative Nature of Science	2, 9
Scientific Theories	2
Relationships Between Science and Technology	10

Table 1: NOS aspect and related items on the questionnaire

Semi-structured Interview

To increase reliability of results taken from open ended items and to gain more explanations about students' responses and to avoid misinterpreting students' responses, a semi-structured interview was used (Lederman, 1992). At the beginning and conclusion of the semester, five students were randomly selected for interview. During the interview, students were provided with their questionnaires and were asked to clarify their responses to certain questions. When a concept, which might be interpreted differently, was found in students' responses, then they were asked to explain and justify their responses. Each interview took approximately 20 minutes and the questions for the interview were semi-structured. Generally the following questions were asked during interviews:
1. Could you give more examples for your response?
2. What do you mean by 'prove' or 'reality'?
3. Is there any difference between scientific theories and laws?
4. Can all scientific knowledge change, even laws?
5. Is there any difference between 'gold mining' (Aikenhead, Ryan, & Fleming. 1989) and producing scientific knowledge?

Science, Technology and Society Course (STS) Content

The STS course is a compulsory course for the senior PSTs who enrol in a four-year elementary science teacher education program. The aim of the course was identified by the Higher Education Council of Turkey as helping the PSTs to develop conceptions about the NOS; developing understanding about the interactions among science-technology-society; gaining skills about scientific inquiry and some others essential knowledge and understanding for effective teaching of science. The course was three credit hours in a semester, which spanned 14 weeks. A professor, who studies experimental chemistry and science education, taught it. The researcher attended all classes as an observer and teaching assistant.

Three ways that nature of science was applied are: lecturing on key concepts; discussions between students in class and projects done by teachers:

The key concepts were NOS, scientific inquiry, project-based science, and science-technology-society interaction. The lectures spanned the entire semester. PSTs were confronted with common misconceptions about concepts included in course content during lectures.

The discussions were done after the presentations of the projects' results and the lectures. It should be expressed that especially the discussions after each lecture and project presentation referred to the explicit aspect of this course and the projects referred to the activity aspect of the course. Each discussion session was 20 minutes long. The PSTs were encouraged to attend these discussions by asking questions and giving feedback to their friends. In general, the instructor or PSTs asked the following questions of project owners or the entire class during discussions:

- How did you ensure the reliability of your results?
- If you could do the same study again, in what ways would you make changes?
- If your research is done by others or with the other sample, will there be any differences between the results?
- During this study process, what do you think about the variables and how they affect you or your results?
- How much are your findings generalized?
- Why did you choose a lot of references or sources in your project?
- How do the limitations and the assumptions of your study affect your results?
- According to you, what are the most original aspects of your project?
- Do you think that your result is a theory or not?
- What kind of evidence is your study based on?
- What did you do for your results to be examined or understood by others?

The main aim of these questions was to link the scientific inquiry activities to the NOS understandings.

The aim of the projects was to engage PSTs in authentic inquiry activities along with explicit reflections. This aim is based on the assumption that conceptions about scientific enterprise and NOS can be developed though instructions in which PSTs engage in scientific inquiries and explicitly reflect on their results in respect to the NOS (Abd-El Khalick, 2001; NRC, 1996). It is not guaranteed that teachers can effectively transfer their understanding about the NOS to their students. To accomplish this goal, teachers should have effective teaching approaches and should have been trained in effective NOS teaching environments. Teachers teach as they were taught (Arends, 2007; Newell, 2003; NRC, 1996). Craven et al., (2002) suggested that providing students with opportunities to express both their tacit and explicit knowledge of the subject in ways, which are consistent with cognitive approaches to pedagogy, might begin the process of developing a richer and fuller conception of science.

The project works consisted of five stages: preparation, data collection, reporting, presentation and evaluation. Each group of PSTs was presented pre-constructed research questions at the beginning of instruction. PSTs were asked to select one out of three research questions, which were previously drafted by the researcher, based on their interests at the beginning of the course. Then, they cooperatively collected and analysed data presented their results in class, and prepared research reports for their project. During preparation, students had the opportunity to read professional articles about their project's subject and interact with the course instructor, the researcher and other professional researchers outside the class. Then students presented their results in class. After each presentation discussions took place to make connections between NOS and the scientific inquiry activities presented. By this way, they were encouraged to voice their own ideas about science.

Through project work, guidance was provided to project groups by the researcher either during class or outside of the class by meeting with each project group individually. In these meetings, explicit connections between their project work and NOS were expressed. PSTs, especially were encouraged to think about their activities in regard to NOS. Each group (PSTs were divided into10 groups) investigated one research question for their project, which was different from the other groups' research questions. Three example research problems:

1. What are elementary students' perceptions about science and scientists?
2. What are the conceptions of scientists from different disciplines about science and technology?
3. How are scientific concepts such as scientific law, theories and hypotheses presented in elementary science textbooks?

Data Analysis

The analysis focused on generating profiles of PSTs' understandings of NOS before and after the STS course followed the explicit project based science. The questionnaire and interview data were analysed using the analytical inductive model of qualitative data analysis approach. All the questionnaires and interviews were treated separately. The entire data analysis was repeated two times to increase the reliability of analysis. It was found that there was almost 80 per cent agreement between the two sets of analyses (Lederman et al., 2002).

To generate each participant's NOS profile, the PSTs' responses to the questionnaire were holistically analysed because there is not a restrictive one-to-one correspondence between an item on the questionnaire and a target NOS aspect (Lederman et al. 2002). The holistic approach in data analysis leads to more accurate profile generation for NOS understanding. When a person can maintain the same understanding in many different contexts, it is valid to infer that this person actually has this understanding

For the inferential statistic test, each participant's response to each item of the questionnaire was classified under three categories, such as '*informed*', '*mixed*' and '*naïve*' based on the following model. Based on this classification, the nonparametric Wilcoxon test was used to compare the pre and post instruction results. This test is used when the data is categorical and the sample is paired.

Informed: If the response included conceptions consistent with the standpoint of current science education literature about the NOS.

Mixed: If the response included both partially informed and naïve conceptions.

Naïve: If the response did not include conceptions consistent with the standpoint of current science education literature about the NOS.

Results

Results show that the majority of PSTs held naïve or mixed views about most aspects of NOS at the beginning of the instruction, there was substantial development in the participants' conceptions about many aspects of science at the end of the instruction; however, little change took place for either conceptions related to the social and cultural influences on science or creativity and imagination in science. See Table 2 and 3.

In the tables and quotations a coding system was used to refer to PSTs and the order of the questionnaire implementation. 'Pre' and 'Post' refer to the order of the questionnaire implementation. The numbers following *'Pre'* and *'Post'* refer to class number assigned to each PSTs.

NOS Aspects	Informed		Mixed		Naive	
	Pre	Post	Pre	Post	Pre	Post
Science	3	78	71	22	26	0
Scientific Theories and Laws	0	58	33	25	67	17
Social and Cultural Influences on Science	15	40	21	14	65	46
Creativity and Imagination in Science	12	29	85	69	3	3
Theory-laden	21	65	61	32	18	3
Differences Between Observation and Inference	36	85	54	15	11	0
Tentative Nature of Science	3	75	69	22	17	3
Scientific Theories	3	76	83	24	14	0
Relationships Between Science and Technology	3	61	32	28	65	11

Table 2: Percentage of PSTs with informed, mixed and naïve views about NOS aspects emphasized in this study at the beginning and end of instruction

Pre-instruction Views of NOS

As shown in the Table 2 PSTs doesn't have informed conceptions about all aspects of NOS at the beginning of the course. There isn't any per cent of PSTs greater than 36% in any aspect of NOS at the beginning of the instruction. Especially, more than 65% of them have naïve conceptions about; functions of and relationships between scientific theories and laws; social and cultural influences on science; as well as functions of, and relationship between science and technology. For science; creativity and imagination in science; theory-laden; differences between observation and inference; tentative nature of science; as well as scientific theories the majority of PSTs have mixed views at the beginning of the instruction. Even though they have some informed conceptions about some aspects of NOS, these conceptions are not well constructed, or they cannot maintain the same conceptions in different situations.

Science

In response to what is science and Technology and how does science differ from non-science subjects, the majority of PSTs do not have informed conceptions. They (83%) define science as a static subject including laws, theories and hypotheses, which are absolute truth and scientists agree on their statuses. PSTs (26%) also explained science as producing technological tools to make life better or easier for people by mixing science with technology. Only approximately a quarter of PSTs (37%) had informed responses to this question by addressing the tentative, developmental, empirical and explanatory aspects of scientific knowledge at the beginning of the instruction. But, they addressed these partially informed conceptions along with some naïve conceptions or they did not incorporate the same conceptions into their responses to the other questions. For example:

> In general, developments about medical, technology, and astronomy to help people live better are called science. Science is static. In science, new discoveries happen based on existing knowledge. Science helps people to gain new knowledge more efficiently. Proven and precise are possible in science. Any result in science can be generalized because there is a single truth in science. Because there is individuality in philosophy and religion, there is also truth (Pre-42).

Tentative Nature of Science

The greater part of the PSTs did not believe that scientific knowledge could change. They (14%) thought that 'since scientific knowledge is proven true it cannot change or unless scientific knowledge is proven true it can change.' Only a few of PSTs (6%) indicated that scientific knowledge could change in their responses.

Similarly, a greater majority of PSTs (91%) believed that unless scientific theories are not proven, they could change and replace others. Only 11percent of them thought that scientific theories can change in the light of new perspectives and more developed technology. In their responses to the pre-questionnaire, many of them articulated that when a scientific theory changes, the previous one is eliminated from science. As an example for theory, they mainly included the atomic theory and the cell theory into their responses. For example:

> A scientific theory can change as long as it does not become a scientific law. At first, the theory of the cell was not the same as the present one. The present one was found after further investigations. This example shows that when a scientific theory is disproved, it changes (Pre-12).

Scientific Theories and Laws

In response to relationships between theories and laws, PSTs mostly articulated beliefs that 'when scientific theories get sufficient support they become laws'; (70%), the 'difference between them is about level of certainty' (76%); and 'laws do not change but theories change' (85%). These results indicated that PSTs believed in a hierarchical relationship between scientific theories and laws, and they also did not know that each of them is a different kind of knowledge. Furthermore, none of PSTs expressed any specific functions of scientific theories (such as explaining), and scientific laws (such as identifying) in their responses. Mostly, they differentiated scientific theories and laws by using terms such as 'proven' and 'unproven'. Note:

> Scientific law is the proven version of scientific theory. Theories are open to further discussion, but laws are not because laws are proven true yet theories are not (Pre-9).

In addition to the written responses, they maintained the same conceptions during the interview as indicated in the following quotation from the interview.

> Researcher: What is difference between scientific theory and law?
>
> Pre-51: Law is more strength than theory. Law is accepted as true by most of the scientists. There are theories about existence of the universe. While these theories are accepted by some they are not accepted by others. But this not case for the law. Every scientist accepts Law. When theory is proven true it becomes law.

Social and Cultural Influences

The majority of PSTs (82%) had naïve conceptions about social and cultural influences on the scientific endeavour. They thought that because science is based on facts and scientific knowledge can be generalized, it does not matter what kind of beliefs, theories, disciplinary backgrounds, prejudices, and preferences scientists have. According to them, scientific knowledge will eventually be purely objective wherever it is done. Only 24 per cent of them thought that the many aspects of social and cultural life influence science. Moreover, many of them believed that if scientists pursue the scientific method, their results should not be different. This last notion also indicates that they had a typical misconception that there is only one scientific method in science. For example:

> Science is universal. Facts in science can be generalized to all people around the world. If science were affected by social and cultural influences, it would be out of its nature. For instance, the law of gravity, which we have been taught in physics, can be generalized to the rest of the world (Pre-12).

Theory-laden

Although, the majority of PSTs did not believe that scientific knowledge is affected by the social and cultural influences, they (64%) admitted that because of individual differences scientists get different results. Some of them (24%) believed that differences in scientific findings is the result of different applications, which are implemented in research, without stating any prior knowledge, assumptions and theoretical commitments, which might effect the interpretation of scientific findings. Similar to conceptions about social and cultural influences on science, some of PSTs (18%) thought that there should not be any differences between results of scientists who do the same experiments. They simply thought that if scientists pursue the scientific method, most of them expressed experiment as the only component of the scientific method; therefore results should not be different. This notion also indicates that they believed there is one universal scientific method in science. Note:

> If every scientist gets the same results it will be a scientific law. The same findings might be interpreted differently (Pre-23).

Creativity and Imagination in Science

Although the majority (97%) of PSTs thought that creativity and imagination are needed in science, only the minority of them (3%) admitted that scientists use their creativity and imagination to invent explanations and models in science. Many of them thought that scientists need creativity and imagination to discover the reality, which has already existed in nature. PSTs, who thought that scientists use their imagination and creativity, restricted this role of scientists only to the design stage of research.

Although a greater majority of PSTs thought that scientists use their imagination and creativity in science, the majority of them (71%) ironically did not admit that scientific knowledge is invented. They simply believed, as influenced by the objectivist point of view, that scientific knowledge has already existed in nature, thus it has been discovered by scientists. Their stress on observation or experimentation showed that they saw scientific knowledge as developing just based on observation or experiment. These PSTs also articulated that scientific knowledge is discovered, but technology is invented. These results indicated that they thought scientific knowledge is discovered rather than constructed by scientists. The following response is an example:

> Scientific knowledge is discovered. For instance, there have been atoms, elements and compounds in nature. Scientists have just discovered this knowledge. But in regard of technology, all technological tools are some kind of invention (Pre-51).

Differences Between Observation and Inference

In response to, what kind of evidence scientists use in science, more than half of PSTs (57%) thought that science is mostly based on experimentation and observation and some of them (11%) believed that it is only based on inference and prediction. It simply means that PSTs thought that knowing is seeing. But, the percentage of PSTs (46%), who had informed conceptions about kinds of scientific evidences, was noteworthy for the beginning of the instruction. Many of them used terms such as experimentation, observation, indirect way, microscope and assumption in their responses intensively. Nearly half of PSTs emphasized the role of experimentation and observation more than the role of inference in science. It was indicated that they were not aware of the importance of inferences in developing scientific knowledge, especially scientific theories. Noting:

> Scientists can observe the structure of atoms by using highly developed technological tools. They get results by using more developed microscopes (Pre-15).

Relationship Between Science and Technology

Very few of PSTs 3 per cent had informed conceptions, which includes that science and technology are different subjects, at the beginning of instruction. The majority of them (76%) held naïve understandings such as "science is the application of technology" about the relationship between science and technology. Some of them (29%) only articulated that science and technology are connected but they did not address any differences between them. For example:

> Technology is the ultimate result of science. Technology cannot be present without science. This means science is the parent of technology. Technology can help science (Pre-21).

Post-Instruction Views of NOS

At the conclusion of instruction, several desired changes were determined in the post-views of PSTs about NOS. These changes are mostly substantial for the majority of NOS aspects. However, for few aspects of NOS the change was not considerable. As a result of non-parametric Wilcoson test (see Table 3), the positive change from naïve to mixed, or informed, and from mixed to informed conceptions, was significant for all aspect of NOS. But, especially changes in conceptions related to social and cultural influences on science, creativity and imagination in science as well as the inventive character of science were not prominent.

NOS Aspects	Total N	Positive Difference	Negative Differences	Tie	p
Science	36	29	0	7	.000*
Scientific Theories and Laws	33	23	0	10	.000*
Social and Cultural Influences	33	14	2	17	.008*
Creativity and Imagination in Science	33	10	4	19	.109
Theory-laden	34	19	0	15	.000*
Differences Between Observation and Inference	26	15	0	11	.000*

Tentative Nature of Science	33	27	0	6	.000*
Scientific Theories	36	28	0	8	.000*
Relationships Between Science and Technology	35	28	0	7	.000*

*p < .05

Table 3: ***The results of Wilcoxon test***

Science

According to the beginning of instruction; there is a substantial change in conceptions of PSTs views related to the definition of science and its difference from other disciplines. At the conclusion of the instruction, the majority of them (89%) expressed that the basic aim of science is to explain the natural world, and this explanation usually opens to change and development in their responses. Only 22 per cent of them still had a naïve conception that science consists of static knowledge, which everybody agrees that it is certain. Participants, who mixed science and technology with each other at the beginning of instruction, completely changed their conceptions in favour of informed conceptions. It was found that while there was an increase in the percentage of PSTs who used terms such as 'change', 'process', and 'facts' there was a decrease in the percentage of PSTs who used terms such as 'proven', 'certainty', and 'making life better' compared to the beginning of instruction. It was disclosed

> Science is an attempt to get an order between sense based evidence and logical thinking. There is not any certainty in science but there is truth in religion. The rules of religion cannot change, but scientific knowledge should be open to all kinds of criticism (Post-3).

Tentative Nature of Science

Substantial changes were evident in the views of PSTs about tentative NOS at the conclusion of the instruction. The great majority of them (78%) admitted that scientific knowledge could change in light of new perspectives shaped by new evidence and technology. More than half the PSTs specifically addressed that there is no 'prove' in science contrary to the beginning of instruction. One of these views explains that:

> There is no certainty and reality in science. Every scientific idea and assumption can change. The knowledge, which cannot be criticism, is religious knowledge. Even if scientific knowledge is accepted, it always should be approached critically (Post-7).

The signs of this improvement in the PSTs' conceptions about the tentative aspect of NOS exists in their oral responses during interview as well as. For example:

> Researcher: Some people claim that scientific knowledge is proven true and should never be criticised. Do you agree with this claim?

> PSTs-Post-12: There isn't any authority in science, because accuracy of any scientific idea can be possible through the other scientists' critics.

Scientific Theories

There was a substantial improvement in the views of PSTs about scientific theories. At the end of instruction, the great majority of them (78%) admitted that scientific theories can change in light of new evidence and developed technology. The Majority of PSTs (91%), who believed that unless scientific theories are proven they can change, refined their conceptions toward informed view, from (91%) to (22%). However, only giving examples such as the atomic and cell theories for scientific theories indicated a deficit in their conceptions. For example:

> Scientific theories can change. In the future, there might be more developed technology. This technology can lead to more sophisticated investigations. Further evidence can lead to changes in scientific theories. For example, because of Einstein's theories Newton's theories changed. Another example is that atomic theories have changed over time (Post-16).

Scientific Theories and Laws

At the conclusion of the instruction half of the PSTs adopted a more informed view that scientific theories and laws are different kinds of scientific knowledge. There was a substantial decrease, from (70%) to (19%) in the percentage of PSTs who thought that theories become laws and from (85%) to (28%) in the percentage of who thought that laws do not change but theories change according to the beginning of the instruction. While there were not any participants who addressed the specific function of theories (such as explaining) and the specific function of laws (such as identifying) at the beginning of the instruction, many PSTs (36%) addressed these functions at the conclusion of the instruction:

> The aim of scientific theory is to explain facts. The aim of scientific law is to identify relationships between facts based on experiments and observations. These relationships are generalizations and usually open to change. Theories and laws are different kinds of scientific knowledge. Gravity is a generalization. The explanation about how salt dissolves in water is an example of scientific theory (Post-10).

Social and Cultural Influences

Although it was not a substantial change, there was some improvement in the conceptions of PSTs about the social and cultural effects on science. The percentage of PSTs who thought that science is affected by the social and cultural factors increased from (24%) to (43%). But, approximately half of PSTs still had naïve views that science is not affected by these factors. This aspect of NOS is one of the aspects, which were not substantially improved through the instruction. It was claimed that:

> Scientists are human like other professionals. It is inevitable to be affected by social and cultural elements. They might want to get results, which do not conflict with their beliefs (Post-19).

Theory-laden

At the beginning of the instruction the majority of PSTs had already informed conceptions about this aspect of NOS. But, at the beginning of the instruction they couldn't attach meaningful explanations to their responses. There was an improvement in this aspect at the conclusion of the instruction. PSTs (18%), who thought that there should not be any differences between results of the same studies, which were done by different scientists, changed their naïve view toward informed view. This view claimed that:

> Differences exist because of different thoughts, which scientists have. Everyone interprets facts based on their point of view For example, when we show something to people, while some of them pay attention to shape and colour, others pay attention to taste or other aspects (Post-25).

Creativity and Imagination in Science

There was not any improvement in the conceptions of prospective teacher in regard to the creativity and imagination aspect of NOS. The majority of them had consistent views with their pre conceptions, which were mixed with naïve and informed views, at the beginning of the instruction. Many of them (40%) still thought that scientists use their creativity and imagination to discover knowledge, which already exists in nature in favour of the objectivist point of view. But their post responses included more explanation about where and how scientists use these characteristics in science as in the following quotation:

> They used their creativity after collecting their data. For instance, even though scientists still are not sure about the structure of atoms, they try to predict its structure by using their imagination and creativity based on the data they collected (Post-41).

Similar to the beginning of the instruction most of PSTs still thought that scientific knowledge has just existed in nature and scientists only discover it. Even though many discussions took place in the instruction to explicitly address this aspect and the differences between discovery and invention, they still did not admit that scientific knowledge is invented. Only six per cent of PSTs changed their conceptions toward informed conception, which is that scientific knowledge is the invention of human’s creativity and imagination. Many of them still thought that technological innovations are invented but scientific knowledge is discovered.

Differences Between Observation and Inference

The percentage of PSTs, who held informed conceptions that scientists use either observation or inferences to put forth scientific theories, substantially changed from 46 per cent to 85 per cent. These PSTs expressed that scientists do experiments and observations at first, then they infer about the aspects of phenomena, which are not observed directly. But, there was still a noteworthy percentage of PSTs who had naïve conceptions that scientific knowledge is solely based on direct evidence. Overall, the majority of PSTs demonstrated informed conceptions about this aspect of NOS at the conclusion of the instruction. For example:

> Let’s think about an object included in a closed box. Even though we cannot see this object, when you shake the box you can predict what might be included in it based on its sound and weight (Post-8).

Relationship Between Science and Technology

Compared to the beginning of the instruction, it was found that there was a substantial improvement in naïve views toward informed views about the relationship between science and technology among PSTs. More than half of PSTs (58%), thought that science and technology are different disciplines. Also, it was found that they addressed that all kinds of tools and methods are products of technology and technology existed before science. One of them claimed that:

> Technology gives the opportunity to people to easily do something, which they cannot do by only using their hands. Technology existed before science. This indicates that technology can survive without science; however in today's world technology and science are highly interconnected. But this does not mean that technology cannot develop without science and it is completely the application of science (Post-35).

Discussion

The main aim of this study was to investigate the effect of an explicit activity based NOS instruction. The results of this study are consistent with the previous studies (Abd-El-Khalick & Lederman, 2000a; Akerson et al., 2000; Gess-Newsome, 2002; Schwartz et al., 2004; Windschitl, 2003), which investigated the effect of explicit approach on teachers' conceptions about NOS. It was determined that this approach was effective in enhancing PSTs' NOS conceptions, which were mostly naïve or mixed at the beginning of the instruction.

At the beginning of instruction the majority of PSTs held naïve conceptions about; relationships and functions of scientific theories and laws; social and cultural influences on science; the inventive character of science and the relationships between science and technology. For the other aspects of NOS, such as definition of science, scientific theories, tentative NOS, theory-laden, creativity and imagination in science and differences between observation and inference, they had mixed views, which were neither informed nor naïve. However, they did not have informed conceptions for any aspect of NOS at the beginning of instruction.

At the end of the instruction, they changed their naïve or mixed conceptions toward informed conceptions regarding the most investigated aspects of NOS. However, their conceptions did not change regarding social and cultural influences on science, creativity and imagination in science, and the inventive character of science aspects of NOS. It was also found that all changes were statistically significant as indicated by the nonparametric Wilcoxon test. Consistent with the results of Abd-El-Khalick and Lederman (2000b), it was found that it is easier to change mixed views, which were partially informed, than naïve views toward informed views.

There is inconsistency between the results of this study and the results of previous studies (Celik & Bayrakceken, 2006) in regard to Turkish PSTs' conceptions about the tentative feature of scientific knowledge. It was reported that the majority of prospective teachers had informed conceptions about the tentative aspect of scientific knowledge. But, in this study, it was found that the majority of PSTs did not have informed conceptions about this aspect of NOS. This difference might be the result of interpreting conceptions of participants in only one context versus in many different contexts. In this study, even though the majority of PSTs articulated that scientific knowledge is tentative, they also thought that scientific theories might change but scientific laws don't when they answered the question about the relationships between scientific theories and laws. This dilemma in their responses indicated that they did not have informed conceptions about this aspect of NOS at the beginning of the instruction.

It was found that PSTs were reluctant to change some naïve conceptions about social and cultural influences on science, imagination and creativity in science and inventive character of science, even though many explicit discussions took place during the instruction on these naïve conceptions, either after their project' presentations or the lectures.

To overcome the challenges to enhance some deep-rooted naïve understandings, there is a need for more developed activities to be used in teacher education or science education. As suggested (Abd-El-Khalick & Lederman, 2000b), some cooperation among science educators, historians of science and other scientists to develop well-matched historical narratives about science along with any NOS instruction, are imperative. Most importantly, NOS instructions should be extended to the all programs of teacher education. During this study, the mostly stated desire of the PSTs was that those kinds of activities, or courses should have been presented to them thorough their training starting at the beginning.

The observations during the course confirmed that only doing science couldn't develop understandings about NOS. Some critical components such as explicit opportunities for reflections and authentic context for scientific inquiry should be incorporated to ensure development of NOS conceptions (Schwartz et al., 2004). In this study, educational research projects provided authentic context. This context enabled PSTs to collect and analyse data, construct explanations and express these explanations both written and verbally. Inquiry context was used to lead reflection. During this process, they were guided toward linking these experiences to NOS explicitly in classes and outside of class discussions. Educational inquiry projects, which were mostly related to NOS and science teaching, were intentionally chosen to confront PSTs to different conceptions about NOS and science teaching, and to compare these understandings with their understandings. Moreover, the project based learning approach was used to model NOS teaching to PSTs.

This study model might be guidance for teachers to use similar model in their instruction for effective science teaching, which incorporates doing inquiry, understandings about inquiry, and teaching inquiry. But only one attempt during the entire teachers' education will certainly not guarantee that teacher will almost adjust this model to their science teaching. For more effective outcomes, they should be confronted with the same model into many different contexts. They should experience inquiry activities along NOS instruction in courses such as chemistry, biology, physics, and other science areas. First of all, prospective teachers should be given chances to express their NOS understandings in instructions.

This study was not designed to investigate the effect of the instruction on their applications as professionals. In addition, it was not designed to determine which component of the instruction; whether authentic inquiry experiences; explicit discussions; or the teaching approach pursued in course, affected PSTs' NOS understandings. These were the main limitations of this study.

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Appendix A

Questionnaire

1. What is science? How are science and other disciplines (e.g., religion, philosophy) are different?
2. After scientists have developed a theory (e.g., atomic theory, cell theory, molecular kinetic theory), does the theory ever change? If you believe that theories do change or do not change explain why?
3. Is there a difference between a scientific theory and law? Give an example to illustrate your answer.
4. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practised. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practised.
    - If you believe that science reflects social and cultural values, explain why. Defend your answer with examples.
    - If you believe that science is universal, explain why. Defend your answer with examples.
5. Scientists perform experiments/investigation when trying to solve problems. Other than planning and design of these experiments/investigations, do scientist use their creativity and imagination during and after data collection? Please explain your answer and give example if appropriate.
6. Some people believe that scientists discover scientific knowledge; others believe that scientists invent scientific knowledge. What do you think about this issue?

- If you believe that scientists discover scientific knowledge, explain your answer with examples.
- İf you believe that scientists invent scientific knowledge, explain your answer with examples.

7. Some astronomers believe that the universe is expanding while others believe that is shrinking; still others believe that universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?
8. What does an atom look like? How certain are scientists about the structure of atom? What specific evidence do you think scientist used to determine what an atom looks like?
9. Some people claim that some knowledge is proofed that is why it should never be criticized during some publicly discussions. Explain whether you agree with this kind of claims or not with examples.
10. What is technology? What kind of relations are there between science and technology if there is any relations?