Australian Journal of Teacher Education

Volume 37 | Issue 2 Article 8

2012

Promoting Pre-service Teachers' Ideas about Nature of Science through Educational Research Apprenticeship

Gultekin Cakmakci
Hacettepe University, cakmakci@hacettepe.edu.tr

Promoting Pre-service Teachers' Ideas about Nature of Science through Educational Research Apprenticeship

Gultekin Cakmakci
Hacettepe University
Turkey

Abstract: This study suggests a novel approach, which integrates an explicit-reflective nature of science (NOS) instruction into the teachers-as-researchers approach to improve pre-service science teachers' conceptions of NOS. Participants were 48 university fourth-year students in a four-year pre-service science teacher-training program in Turkey. The participants received explicit-reflective NOS instruction and were introduced to some techniques for critically evaluating academic articles, designing and conducting a research project, writing a research report and preparing materials to share the findings of their studies with students and staff of their department at a poster conference. During these activities, the lecturer explicitly addressed the target aspects of NOS and made pre-service science teachers' thinking more visible and reflective. The Views of Nature of Science Questionnaire (VNOS-C) was used in conjunction with individual interviews to assess participants' NOS views at the beginning and conclusion of the study. The results indicated that compared with their ideas at the beginning of the course, many pre-service science teachers had developed more 'informed ideas about NOS' throughout the course. The significance of this study is that carrying out an educational research with the incorporation of an explicit-reflective instructional model seems to be a promising avenue to improve pre-service science teachers' ideas about NOS. Some possible implications for pre-service and in-service teacher education and further research are discussed.

Introduction

Emphasis on teaching about the development of knowledge and its application in contemporary settings has been increasing within many science curricula (for example, American Association for the Advancement of Science (AAAS), 1995; Nuffield Twenty First Century Science, 2007; Turkish Science and Technology Education (MEB), 2005). Today, it is widely agreed that understanding the nature of science (NOS) is an essential component of public engagement with science and scientific literacy (Driver, Leach, Millar & Scott, 1996; Millar, 2006). What is NOS? There is no simple answer to this question. The phrase usually used to refer to 'the epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development' (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002, 498). Due to new research, innovations and ways of understanding about science, conceptions of NOS are likely to change in the future. Although there is no single and universally accepted definition of NOS (Cobern & Loving, 2001; Rudolph, 2000) at present, an academic consensus has been achieved on the basic aspects of NOS to be taught in school science (AAAS, 1995; Abd-El-Khalick & Lederman, 2000a; Lederman et al., 2002; McComas, 1998). These aspects are that scientific knowledge is (a), both reliable (one can have confidence in scientific knowledge) and tentative (subject to change in light of new evidence or new perspectives); (b), empirically based (based on and/or derived from direct or indirect observations of the natural world, although no single, universal scientific method captures the complexity and diversity of scientific investigations); (c), subjective and/or theory-laden (scientists' values, knowledge, and prior experience as well as contemporary scientific perspectives influence their observations and the collection and interpretation of empirical data); (d), partly the product of human imagination and creativity (involves the invention of theories and laws); (e), socially and culturally embedded; (f), subject to a distinction between *observations* and *inferences*, and (g), subject to distinctions between the functions of, and relationships between, scientific *theories* and scientific *laws* (Abd-El-Khalick and Lederman, 2000b, 1063). These seven NOS aspects, which were targeted in this current study, are consistent with views emphasized in recent policy (for example, National Science Teachers Association, 2000) and reform documents in science education, such as *Science for All Americans* (AAAS, 1995), *Nuffield Twenty First Century Science* (2007) and *Turkish Science and Technology Education* (MEB, 2005). Nonetheless, it is important to note that there are other NOS aspects that a contemporary philosopher (Allchin, 2011; Alters, 1997; Irzik & Nola, 2011), sociologist of science or researcher might include or omit (Clough & Olson, 2008; Osborne, Ratcliffe, Collins, Millar & Duschl, 2003; Yalaki & Cakmakci, 2010).

The relationship between teachers' views of NOS (subject matter content knowledge) and transferring them into classroom practice (pedagogical content knowledge) is a complex and challenging issue (Akerson, Cullen & Hanson, 2009; Brickhouse, 1990; Hanuscin, Lee & Akerson, 2011). Subject matter content knowledge, according to Shulman (1986), includes not only facts, theories, laws and concepts, but also ideas about how that knowledge is generated and structured in the discipline. However, pedagogical content knowledge 'goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge *for teaching*' (Shulman, 1986, 9). Teachers' subject matter content knowledge (in this case, their epistemological knowledge and their ideas about NOS) is an essential, but not sufficient, element in teaching and learning processes in that their subject matter content knowledge either enhances or hinders their students' learning (Abd-El-Khalick & Lederman 2000a; Hanuscin et al., 2011). Some of the conceptual difficulties encountered by students are associated with those of their teachers. Therefore, it is essential that pre-service science teachers (PSTs) possess an appropriate understanding of NOS and effective pedagogical practices in order to help their students to learn these ideas properly. This is one of the reasons for choosing PSTs as a sample for this study.

Research on the views of pre-service teachers (Abd-El-Khalick, 2005; Kucuk, 2008), in-service teachers (Akerson et al., 2009; Guerra-Ramos, Ryder & Leach, 2010) and lecturers on NOS (Irez, 2005) show that the greater majority of them have several naive NOS views, which are inconsistent with contemporary interpretations of the NOS (Lederman, 2007). For this reason, several attempts were undertaken to improve students and teachers' NOS views (Abd-El-Khalick, 2005; Leach, Hind & Ryder, 2003; Seker & Welsh, 2006). Researchers have used approaches that vary along a continuum from implicit to explicit in their attempts to enhance students and teachers' NOS views (for example, Abd-El-Khalick & Lederman, 2000b, Clough, 2006) (see Figure 1).

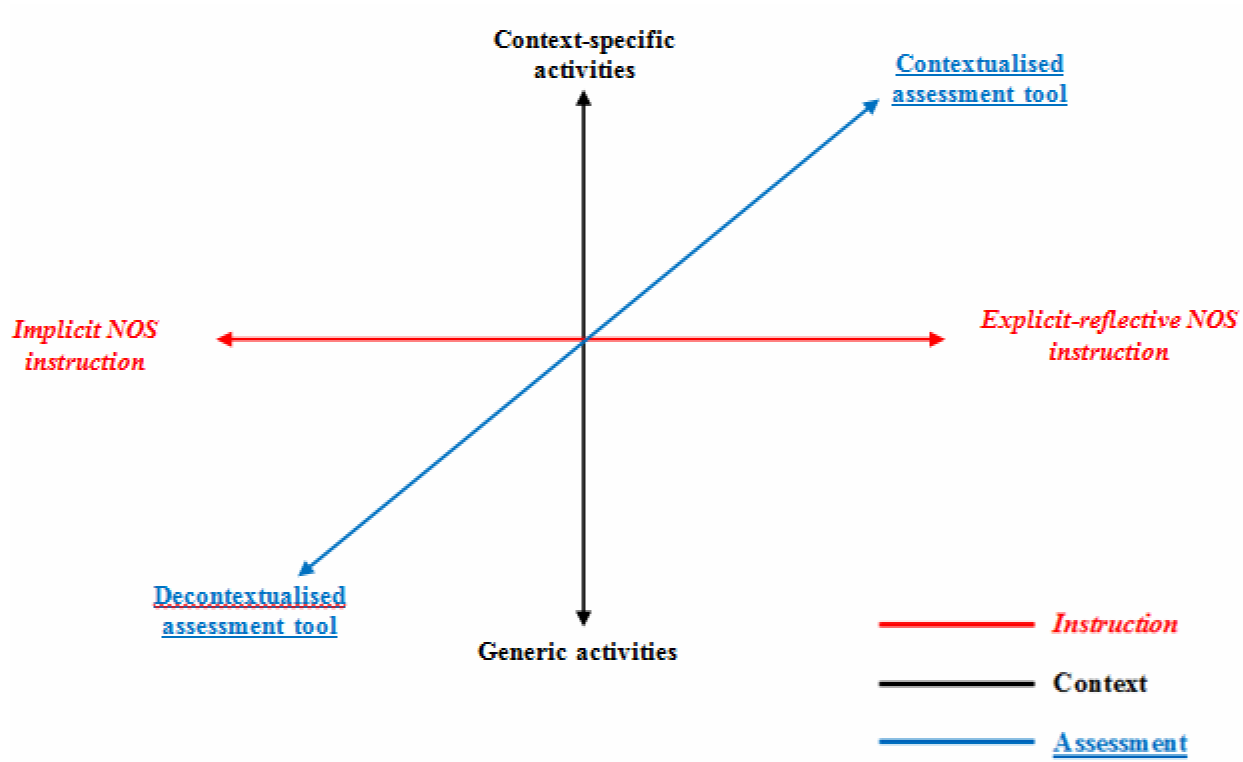

Figure 1: Implicit versus explicit-reflective NOS instruction, generic versus context-specific activities for teaching NOS, and decontextualised versus contextualised tools for assessment of NOS

Several researchers have suggested that an *explicit-reflective approach* (for example, Abd-El-Khalick, 2005; Akerson, Abd-El-Khalick & Lederman, 2000; Kucuk, 2008) to develop students' NOS views is relatively more effective than an *implicit approach* (for example, Haukoos & Penick, 1985) that utilises hands-on or inquiry science activities lacking explicit references to NOS. The implicit approach assumes that learners will learn NOS as a natural consequence of the engagement in scientific inquiry activities (Schwartz, Lederman & Crawford, 2004). However, research on students, teachers, and scientists' views of NOS show that the subject who engages in scientific inquiry alone does not necessarily develop contemporary views of NOS (Bell, Blair, Lederman & Crawford, 2003; Schwartz et al., 2004). The main criticism to the implicit approach is that during teaching, teachers and students are often unclear about the learning aims of teaching activities related to NOS (Leach et al., 2003). In most cases, science is not there to be discovered through close scrutiny of the natural world; rather, it involves introducing students to the scientific ideas and ideas about NOS (Leach & Scott, 2002). As Scott, Leach, Hind & Lewis (2006, 62) put it, 'learning science involves being introduced to the language of the scientific community and this can be achieved through the agent of a teacher or some other knowledgeable figure'. It becomes clear that teachers are central to this process, as they take on the role of interpreters, facilitators or mediators of the language of the scientific community (Mortimer & Scott, 2003). Several researchers agree that teaching about NOS is important and it should be addressed explicitly and reflectively within *contextualised* activities rather than only within *generic (decontextualised)* activities (Clough, 2006; Duschl, 2000; Sadler, Burgin, McKinney & Ponjuan, 2010; Schwartz et al., 2004) (see Figure 1). They also argue that not only should aspects of NOS be explicitly taught, but also explicitly assessed within relevant contexts (Clough & Olson, 2008; Guerra-Ramos et al., 2010; Hanuscin et al., 2011; Tasar 2005).

Theoretical Foundations

In this study, an explicit-and-reflective NOS instruction was used as a pedagogical framework in the context of educational research apprenticeship. The use of a cognitive apprenticeship instructional model (Collins, Brown, & Holum, 1991; Rogoff, 1990), among others, is suggested for bringing the tacit ideas about NOS into the open, where learners can identify, practise and make sense of them in an educational research context with help from the tutor and/or some other knowledgeable figure - what might be called ‘guided practice’ (Collins et al., 1991). Cognitive apprenticeship reflects situated learning theory (Collins et al., 1991). According to situated learning theory, knowledge is situated in social, cultural and physical contexts in which it is developed and used; therefore, teaching activities that are embedded in authentic situations are essential (Brown, Collins & Duguid, 1989).

Our work has been influenced by a number of researchers who have argued that science educators and teachers should explicitly guide learners in their attempts to develop more appropriate understanding of the nature of the scientific enterprise in the context of activities, investigations and historical examples (Abd-El-Khalick & Lederman, 2000a, 2000b; Aydeniz, Baksa & Skinner, 2011; Clough, 2006; Sadler, 2009; Schwartz et al., 2004). However, what is novel in this study is that educational research is used as a context for learning NOS. During this activity, the participants’ attention is drawn to aspects of NOS by making links between NOS aspects and components of the educational research activity. Within the framework of situated cognition (Brown et al., 1989; Lave & Wenger, 1991), it is claimed that engagement in research similar to that of researchers does provides a context for the learner to develop informed ideas about NOS (Sadler, 2009; Sadler et al., 2010; Schwartz et al., 2004; Schwartz & Crawford, 2006). Nonetheless, the nature of research can range from brief classroom activities (Seker & Welsh, 2006) to long-term projects in research laboratories (Seymour, Hunter, Laursen & Deantoni, 2004) or to research into educational issues (Cakmakci, 2009). Studies on learning NOS through research apprenticeship suggest that participants who demonstrate gains from research experiences benefit from interaction with tutors who explicitly address some NOS aspects and make students’ thinking more visible and reflective (Bell et al., 2003; Sadler et al., 2010). Although there are some studies that have investigated the influence of research experiences on participants’ views of NOS (Aydeniz et al., 2011; Bell et al., 2003; Grindstaff & Richmond, 2008; Sadler et al., 2010), there are very little empirical data available on how ‘educational research’ influences participants’ views of NOS (Lederman, 2007). It is important to note that the norms, methods, assumptions, techniques, products and practice of natural sciences may be different from those of social sciences. Therefore, it is important to investigate the effect of educational research on participants’ NOS views. Carrying out educational research offers a context-oriented learning environment (Brown et al., 1989) and provides opportunities for participants to construct their own understandings through contextual teaching. It is assumed that bringing the tacit ideas about NOS into the open, where learners can practise them in an appropriate context will promote participants’ ideas about NOS (Clough, 2006; Schwartz et al., 2004). Guided participation is used to direct participants’ actions and to provide feedback and reflections on the consequences (Mercer, 1995; Rogoff, 1990). The key assumptions behind this study are that *explicit* teaching of the crucial aspects of NOS within appropriate contexts and more emphasis on students’ difficulties in understanding NOS can improve the participants’ understanding of NOS.

Research Aims and Significance of the Study

Although various attempts have been made to improve teachers' NOS views, the results of relevant studies have shown that alternative strategies should be considered (Lederman, 2007). The present study suggests a novel approach that integrates an explicit-reflective nature of science (NOS) instruction (Abd-El-Khalick, 2005; Akerson et al. 2000) into the teachers-as-researchers approach (Cakmakci, 2009; Cochran-Smith & Lytle, 1999; Roth, 2007; van Zee, 1998) to improve PSTs' conceptions of NOS. By conducting educational research, PSTs can gain a deeper understanding of it (Demircioglu, 2008) and become aware of students' difficulties in science and NOS (van Zee, 1998). By enabling them to work like educational researchers, such activities could help PSTs to construct better understandings of certain aspects of NOS and provide a context for teaching and learning NOS. The context includes more apprentice-like situations (Bell et al., 2003; Rogoff, 1990) in which PSTs collaborate with one another and with their lecturer in moving toward some shared understanding about NOS. During educational research projects, PSTs actively engage in educational research processes and meaning construction, with the lecturer's guidance, to understand the desired NOS aspects (Schwartz et al., 2004).

Although the arguments given above seem reasonable, there are very little empirical data available on the evaluation of teacher research and on how such experience influences participants' views of NOS (Lederman, 2007). What is largely missing from the literature is the nature of teacher research and its role in teacher preparation and professional development programs. Hence, there is a need to understand how the design of an environment supports PSTs' enactment of small-scale educational research projects and influences their views of NOS. Bearing these points in mind, this study aimed to assess the effect of a course that integrates explicit-reflective NOS instruction into the teachers-as-researchers approach on PSTs' NOS views.

A pre-test/post-test repeated measures design was used to address the research aim. Activities that would facilitate PSTs' NOS views were developed, implemented and evaluated. PSTs' responses to written questions and to interview questions were used as data sources for exploring the changes of their NOS views during the intervention.

Design and Methodology

Participants of the study were 48 university fourth-year students (30 women and 18 men aged 21-22 years) in a four-year pre-service science teacher-training program in Turkey. Participants took the *Special Topics in Science II* (*STiS II*) course in the spring semester of their final year. PSTs who participated in this study will become upper primary school (Grades 6-8) science teachers when they graduate. The study was undertaken in a public university in Ankara during the 2006-2007 academic year.

Participants Pre-knowledge about Research Methodology and NOS

PSTs were taught about basic educational research methodology by a different lecturer in the previous semester in the course *STiS I*. Some aspects of NOS were addressed in a course called *Science, Technology and Society*, which was also taught by a different lecturer in the previous semester.

Context and Instructional Strategies

The study was undertaken in the context of the *STiS II* course, which was taught by the author. Classes were held weekly in three-hour blocks throughout the semester (14 weeks). The course aimed to help PSTs (a), contextualise the target aspects of NOS; (b), gain the knowledge and skills to design, carry out and report on a small-scale research study; (c), work collaboratively; (d) communicate their findings to others at conferences or through other means; and (e) to envision themselves as researchers for lifelong learning. The design of the course was informed by evidence from educational theories and research data on PSTs' ideas about NOS (see Figure 1). In addition, our experience with the previous cohort and their views on the course were drawn upon to design the course content.

Strategy 1: Critical Analysis of Research Papers

Science is a public enterprise, a critical component of which is the communication of research findings. In Week 2, the lecturer gave a presentation on types of research and research writings. This presentation was mainly based on the issues discussed in an article by Millar (2003) entitled 'Communicating your research to others'. After this lecture, an empirical educational research paper was given to participants to read until Week 4. In Week 4, that paper was analysed in terms of some methodological requirements discussed in Millar's (2003) and Sozbilir's (2007) articles. Participants were encouraged to address several questions through this analysis, such as: What does the study aim to achieve? What is the research method employed? What are the main findings of the study? In following weeks, each group was asked to find a journal article on students' understanding in science and/or NOS, read it critically and prepare a short presentation (10 minutes followed by 10-20 minutes' discussion). Each week one or two groups presented and all PSTs were supposed to read the articles before the session so that they could contribute to the discussion. The lecturer drew the PSTs' attention to the target aspects of NOS through discussion, guided reflection and specific questioning in the context of each research paper. This activity aimed to reinforce participants' understanding of the ideas presented and to provide them with opportunities to consolidate and enhance their knowledge about the content and structure of academic articles and NOS.

Strategy 2: Conducting Educational Research

During the *STiS II* course, PSTs conducted two research projects: 'practice study' and 'main study'. In the second week of the course, a number of questions (for example, 'What do you think about building a nuclear power plant in Turkey?' 'How do seasons occur?' 'What do you think of experimenting on animals?') were introduced to participants and they were asked to carry out empirical research in groups of 4-6 to investigate responses to one of those questions in a sample of students, staff or lay people. This study was considered a 'practice' exercise. In the third week of the course, PSTs presented their findings (10 minutes' presentation followed by five minutes' discussion). This activity aimed to engage participants in reflection on research aims, methodology, research instruments, data analysis, results and discussions. During their presentation, the strengths and weaknesses of the educational research were also discussed.

From the beginning of the course, the participants were asked to choose a research area, formulate investigable research questions and design and carry out a small-scale educational research study in groups of 2-6. The topics chosen for the 'main study' were dependent on the participants, but they were guided by the lecturer. For instance, the lecturer introduced some of the research projects that had been carried out by the previous cohort. In addition, the lecturer encouraged the PSTs to discuss their ideas with both university and school staff to ensure they had a viable research project. The topics chosen for the research are presented in Table 1. During regular classroom teaching (Strategies 1, 3 and 4) and supervisions meetings (Strategy 5), PSTs were engaged in discussion of the target aspects of NOS. For example, they were reminded that no single, universal scientific method captures the complexity and diversity of scientific investigation; rather, various approaches and different methods might be used during an investigation (Hanuscin et al., 2011). During teaching, the lecturer explicitly helped PSTs to recognise that what they had been doing in their research study was in some ways similar to what some scientists do. If we summarize PSTs' research, they mainly followed the following phases of research: idea generating, problem-definition, procedures-design, data collection, data-analysis, interpretation and communication phases.

Group *(number of pre-service teachers)*	**Research Topic**	**Design & Instruments**	**Participants**
A(6)	Teachers' views on the 6th grade science and technology education curriculum	Survey Semi-structured interviews: 10 open-ended questions	18 elementary science teachers
B(2)	The effect of using teaching materials on 7th grade students' understanding of the concepts of solid and liquid pressure	A quasi-experimental design 11 multiple choice questions	60 7th grade students (27 experimental, 33 control)
C(4)	Investigating 6th grade students' ideas about recycling	A longitudinal study 6 open-ended questions in conjunction with follow up individual interviews	59 6th grade students
D(4)	Investigating 8th grade students' misconceptions about heat and temperature	Survey 16 two-tier questions	77 8th grade students in three different schools
E(5)	A study of primary school students' (6th -8th Grades) images of scientists	Survey A modified version of the Draw-A-Scientist Test	79 primary school students
F(6)	A study of making 6th grade students conscious about heat conservation	A quasi-experimental design 5 open-ended questions in conjunction with follow up individual interviews (6 experimental, 6 control)	52 6th grade students (24 experimental, 28 control)
G(2)	Investigating 7th grade students' attitudes towards water conservation	Survey 63 five-point Likert-type items	50 7th grade students
H(6)	Investigating children's interests by analysing science-related questions submitted to a popular science magazine called *Science and Children*	Document analysis Analysis of 354 students' self-generated questions	Analysis of 354 students' self-generated science-related questions submitted to a popular science magazine called *Science and Children*
I(2)	Teachers and pupils' views on doing experiments in 6th grade and their views on constrains on the use of laboratory activities.	Survey 12 open-ended questions for students and 17 open-ended questions for teachers	Pilot study: 30 students Main study: 50 students and 4 science teachers
J(6)	Teachers' views on the theory of evolution and on the way the new Turkish Science and Technology Curriculum addresses this concept	Survey Semi-structured interviews: 8 open-ended questions	10 primary school science teachers

K(3)	The effect of a science and mathematics integration program on students' understanding of the concept of light	A quasi-experimental design 39 multiple choice questions	32 6th grade students (17 experimental, 15 control)
L(2)	4th year science pre-service science teachers' conceptual understanding of genetics	Survey 10 open-ended questions in conjunction with follow up individual interviews (n=4)	Pilot study: 10 fourth year science pre-service science teachers Main study: 30 fourth year pre-service science teachers

Table 1: Topics chosen for a small-scale research project

Strategy 3: An Explicit-Reflective NOS Instruction

In Weeks 4 and 6 (in total, four hours), participants engaged in different activities that were coupled with explicit-reflective NOS instruction (Abd-El-Khalick, 2005; Akerson et al., 2000) to address seven target aspects of NOS. These activities were selected as they have been successfully used with school students and PSTs to enhance their conceptions of NOS. The detailed descriptions of these activities can be found in Lederman & Abd-El-Khalick (1998) and *Nuffield Twenty First Century Science* (2007). One of the activities (*Tricky Tracks*) addressed differences between observation and inference and the empirical, creative, imaginative, and tentative nature of scientific knowledge. Three activities (*The aging president, Young? Old? and Rabbit? Duck?*) targeted the theory-laden and social and cultural embeddedness of science. Two other activities addressed the function of and relationship between scientific theories and laws (Lederman & Abd-El-Khalick, 1998). Finally, three activities (*Football boots, Is Mr Briggs Guilty of Speeding?* [*Nuffield Twenty First Century Science*, 2007] and the *Periodic Law*) were used to reinforce participants' understandings of the above NOS aspects. Each activity was followed by a whole-class discussion that aimed to engage participants in active discourse to *clarify and reflect* on their views (Mortimer & Scott, 2003) of the target NOS aspects. An explicit-reflective approach emphasised participants' *awareness* of the target NOS aspects within different contexts. It should be noted that, unlike Strategy 2, most of these activities in Strategy 3 were generic (see Figure 1).

Strategy 4: Reading and Discussing Papers Related to NOS

Over the course of three instructional hours spanning Weeks 5 to 7, three readings related to NOS and scientific literacy (Bagci-Kilic, 2003; Turkmen, 2006; Yildirim, 2005) were used to explicitly introduce participants to the crucial aspects of NOS and to reflect on seven target aspects of NOS. The lecturer helped PSTs to move back and forth in order to make links between different concepts introduced to them through teaching. Such structured activities aimed to provide participants with opportunities to *consolidate and reflect upon* their knowledge (Mercer, 1995) about NOS.

Strategy 5: Supervision Meetings

As a result of the lecturer's experience with the previous cohort, it had become obvious that PSTs needed supervision meetings throughout their research projects. Each group had four regular compulsory meetings. Each supervision meeting lasted around 20 minutes. Beyond this, some additional meetings were arranged if any group of PSTs asked for them or if the lecturer thought the PSTs needed more supervision. Each additional supervision meeting lasted approximately 10-20 minutes. In some cases, rather than face-to-face meetings, PSTs preferred e-mail contact to discuss problems they came across. The purpose of supervision was to give PSTs theoretical, methodological or technical guidance and support in relation to their projects (for example, how to use *SPSS* [http://www.spss.com] software and database applications such as ERIC [http://www.eric.ed.gov]). If the lecturer was not able to guide them, another who had relevant expertise was sought. For instance, a biology educator was asked to check the content validity of data collection instruments for Groups J and L. It should be pointed out that during supervision meetings the lecturer raised questions to compel PSTs to consider NOS aspects inherent in their authentic research experiences, encouraged PSTs to reflect on their research, and explicitly addressed some of the desired NOS aspects. In other words, the lecturer directed participants' actions and provided feedback and reflections on the consequences (Mercer, 1995; Rogoff, 1990).

Strategy 6: Oral Presentation

Each group of PSTs presented their work toward the end of the course (10 minutes' presentation and five minutes' discussion). This activity, similar to conference presentations in nature, aimed to engage participants in order to reflect the research aims, methodology, research instruments, data analysis, results and discussions. During the presentations, the strengths and weaknesses of the educational research were also discussed. This activity (and Strategy 8) enabled participants to exchange and disseminate their knowledge and experience with peers (Mercer, 1995), argue points, answer questions, respond to critiques of their work and question others in a collegial manner. It was also emphasised here and in Strategy 8 that science is a set of socially-negotiated understandings of the universe and the scientist who proposes a theory or claim shares those ideas and tries to convince other scientists. Scientific knowledge is accepted if it is deemed viable by the scientific community, but still there may be different views among scientists (Lederman & Abd-El-Khalick, 1998).

Strategy 7: Writing Reports

After completing their projects, PSTs were required to write reports on their educational research. Baker (2004) claims that writing research reports and subsequently drawing on them to make presentations to their peers (Strategies 6 and 8) play key roles in the construction of scientific knowledge, metacognitive knowledge, and understanding of NOS. Indeed, reading, writing, and speaking are closely linked to understanding science and, by extension, to learning science (Mercer, 1995; Baker, 2004).

Strategy 8: Poster Conference

In addition to the written reports, PSTs prepared materials to share the findings of their studies with students and staff of the department at a poster conference toward the end of the course. Such structured activities, e.g. Strategies 6 and 8 helped PSTs to envision themselves as researchers as they formed identities as teachers (Bennett & Campbell, 2002; van Zee, 1998).

Data Collection and Instruments

This study aimed to assess the effect of *STiS II* course that integrated an explicit-reflective NOS instruction into the teachers-as-researchers approach on PSTs' NOS views. To address the research aim, an approach involving the analysis of questionnaires and interviews was employed.

(A) The Views of the Nature of Science Questionnaire-Form C (VNOS-C)

The VNOS-C (Lederman et al., 2002), consisting of 10 open-ended questions, was used to probe participants' explicit statements about the target NOS aspects, contextualised in examples of the participants' choices. The questionnaire had previously been used with in-service and pre-service teachers and validated by many researchers (Abd-El-Khalick, 2005; Lederman et al., 2002; Schwartz et al., 2004). The questionnaire included both decontextualised and contextualised questions, and assessed each aspect of NOS with more than one question. The open-ended nature of the questions allowed respondents to express themselves by using 'their own words and examples, without being forced into a choice and/or words being chosen for them' (Schwartz et al. 2004, 622). Therefore, the information gathered was more likely to give a fuller insight into respondents' views.

(B) Semi-Structured Interviews

After the administration of the VNOS-C, a surface analysis of responses was conducted and possible interviewees were selected. A sub-sample of the participants (N_{pre}=3, N_{post}=7) were selected to represent diversity in responses to the written questions, to probe their understanding of NOS in more depth and to check for appropriate interpretation of the written responses to the VNOS-C. The main consideration was to ensure the coverage of the all questions and to select as representative a sub-sample as possible. Other factors affecting selection included PSTs' perceived willingness to talk freely about their ideas. The participants in the pre- and post-instruction interviews were different. The interviews lasted from 30 to 60 minutes and were recorded for analysis. During the interviews, the participants were provided with their pre- or post-instruction questionnaires and asked to justify their responses and provide examples to illustrate and contextualise their views.

(C) The Teacher Research (TR) Questionnaire

At the end of the course, a questionnaire composed of eight open-ended questions (TR Questionnaire) was distributed to the PSTs and a sub-sample of them (N_{post}=7) was interviewed in order to investigate their views on the value of undertaking small-scale research. Due to space limitations, the results of the TR Questionnaire are not presented in this paper and only one question in relation to their understanding of the NOS from the Questionnaire is discussed: 'What were the most and least effective methods for you to learn ideas about nature of science throughout the *STiS-II* course?' Thus, we got an insight into (from PSTs' points of view) the most and least effective methods for learning NOS. Participants were instructed not to write their names on the TR Questionnaire so that their responses would remain anonymous and be more genuine.

Data analysis

The VNOS-C was administered to 44 PSTs at the beginning and 47 at the conclusion of the study. Forty participants' responses were analysed and the others who took either only the pre- or post-test were eliminated from the analysis. This allowed us to identify how individual participants' conceptions changed throughout the course. A coding scheme developed by Lederman et al. (2002) was used to analyse the data. Three main categories of responses were identified and used in reporting results: (1), responses with naive views of NOS; (2), responses with informed views of NOS; and (3), uncategorised responses. Detailed examples of these coding categories are described in the results section. Interview responses provided by ten PSTs were analysed and each individual participant's responses to the VNOS-C questionnaire were compared to his/her responses in the more open interview context in order to assess the consistency of the participant's responses. Cases in which PSTs elaborated or changed their responses during the interview were also noted. After this process, all VNOS-C questionnaires were analysed to generate pre- and post-instruction profiles of participants' views of NOS (see Table 2).

	Pre-instruction NOS views (n=40)		Post-instruction NOS views (n=40)		McNemar's test	
	Naïve Views (%)	Informed Views (%)	Naïve Views (%)	Informed Views (%)	McNemar's Value	**n**
Tentative NOS	55	45	13	85	0.000***	39
The empirical NOS	55	45	33	67	0.035**	40
Theories and laws	95	3	50	50	0.000***	39
Observation versus inference	30	38	13	75	0.039**	26
Subjective (Theory-laden)	40	38	8	83	0.000***	30
Creative and imaginative NOS	40	60	25	73	0.146*	39
Social and cultural influences	75	20	20	75	0.000***	37

Table 2 Percentage of participants with naive and informed views of NOS and summary of the McNemar's test

Notes: McNemar's test compares the participants' naïve and informed views from pre- to post-instruction. Binomial distribution is used. * Not significant, ** Significant at $p<0.05$, *** Significant at $p<0.001$.

In order to ensure the reliability of the analysis, the researcher gave some training to a fellow researcher to test the inter-coder reliability of the coding scheme. The fellow researcher had completed his PhD in the United States with a thesis on the influence of teacher world views on science teaching. Ten questionnaires were coded together with the researcher and the independent coder. Then twelve randomly-selected questionnaires out of 80 (15 per cent) were coded by the independent coder. The inter-coder agreement was found to be 86 per cent and the Cohen's Kappa value was calculated 0.79, which was considered high (Ericsson & Simon, 1993). The remaining differences were resolved by negotiation between the coders.

Results

The following sections present PSTs' pre- and post-instruction views of NOS. The results indicated that, compared with their ideas at the beginning of the course, PSTs developed informed ideas about NOS throughout the course. As evident in Table 2, these changes were mostly substantial and observed in the case of all seven NOS aspects. As for the quantitative analysis, a McNemar's test was used to compare the participants' naive and informed views from pre- to post-instruction testing for each NOS aspect. The analysis revealed statistically-significant changes from pre- to post-instruction in participants' views of the target NOS aspects, but no statistically-significant changes were identified about their views of the creative and imaginative nature of scientific knowledge. In the text, the quotations taken from PSTs' written responses and the transcripts were identified with the codes such as [Q_{pre}-02]. Q_{pre} and Q_{post} stand for pre- and post-instruction VNOS-C questionnaire and I_{pre} and I_{post} stand pre- and post-instruction interviews respectively and the number shows the PSTs' numbers. Item number indicates the question number in the VNOS-C.

Tentative Aspects of NOS

At the beginning of the study, about 55 per cent and at the end, about 13 per cent of the PSTs held naive views of the tentative NOS. Some pre-instruction interviewees, who wrote that scientific theories might change, expressed this opinion in the sense of adding new knowledge to current knowledge (accumulative change) (Khishfe & Abd-El-Khalick, 2002). None of these participants' written pre-instruction responses included the view that scientific knowledge is subject to change in the sense of abandoning or rejecting earlier scientific claims about natural phenomena and adopting others (revolutionary change) (Khishfe & Abd-El-Khalick, 2002). Several participants indicated that scientific theories might change with the advent of new evidence and technological development, but a large majority believed that laws are proven to be correct and they will not change in the future. In most cases, they mentioned that science differs from other disciplines of inquiry in that scientific knowledge is definite, correct or proven to be true. As one of the participants put it:

> *…science is different from other disciplines in that it is concrete and can be proven* [Item-1]*…Theories can change in the future, but laws cannot change. Because, they are proven [to be true].* [Item-4]. [Q_{pre}-02]

Quantitatively, a McNemar's test was used to compare the percentage of PSTs' naive and informed views from pre- to post-instruction for the tentative aspect of NOS (see Table 2). The results revealed statistically-significant changes from pre- to post-instruction in participants' views (n=39, p<0.001). By comparison, at the beginning of the study, about 45 per cent of PSTs and at the end of the study, about 85 per cent, described a tentative view of science. Many either explicitly or implicitly noted that there is no such thing as absolute truth in science, and scientific knowledge may change in the future. The following quotation also illustrates this view:

> *Change and development are essential components of science. We can explain this with an example. Ptolemy propounded the earth-centred universe model…But later on a scientist, called Copernicus, proposed that the Earth revolves around the sun, the sun-centred universe model….However today based on our observations and collected data, we know that the sun revolves and it is just one of the millions of stars in the Milky Way galaxy. In science, theories or laws change in two ways. One [is] accumulative [and] two [is] revolutionary.* [Item-4]. [I_{post}-05]

As is partly evident from the above, participants were not only aware of accumulative change, in which new knowledge, new technology and new discoveries add to old ones, but also aware of revolutionary change, in which new ideas contradict older ones and replace them.

Empirical Aspects of NOS

Prior to the instruction, 55 per cent of the PSTs and after the instruction 33 per cent demonstrated naive views of the empirical aspect of NOS. Although the empirical base of scientific knowledge was commonly accepted by the majority of PSTs, many of them presented naive ideas about the empirical aspects of NOS. For example, most of them equated knowing with seeing. They seemed to believe that science and the development of scientific knowledge rely solely on direct evidence obtained from experiments or observations; therefore, science is solely about facts. They argued that science is different from religion in that scientific claims are definite, universal and can be proven, but religious beliefs and claims can vary according to different cultures and cannot be experimentally proven. The following partly illustrates this view:

> *Science always depends on the proven facts. It is rational. There cannot be a number of views, but there is one proven truth. However, there would be more than one view in philosophy and metaphysics and there is not one truth.* [Item-1]. [Q_{pre}-35]

Furthermore, as quoted below, several participants claimed that there is a universal scientific method, which distinguishes science from other disciplines, such as religion. They believe that this method is a stepwise procedure and all scientists follow it when they do science. This finding has been commonly reported in other studies as well (Irez, 2006; McComas, 1998):

> *Science is not something that differs from person to person. Scientific process includes following steps: defining the problem, constructing the research question, collecting data and based on that data the proposed hypothesis can be rejected or proven.* [Item-1]. [Q_{pre}-20]

The number of PSTs with informed views of the empirical aspect of NOS increased from pre- to post-instruction. Prior to the instruction, about 45 per cent and after the instruction about 67 per cent of the PSTs demonstrated informed views of the empirical aspect of NOS. Analysis of the McNemar's test analysis indicated statistically-significant changes from pre- to post-instruction in participants' views ($n = 40$, $p<0.05$). The following quotation illustrates how a PST elaborates her response after the instruction:

> *Experiments are a kind of method that helps to collect data to support scientific knowledge.* [Item-2]… *Ptolemy propounded the earth-centred universe model…But later on a scientist, called Copernicus, proposed that the Earth revolves around the sun, the sun-centred universe model….However today based on our observations and collected data, we know that the sun revolves and it is just one of the millions of stars in the Milky Way galaxy.* [I_{post}-05]

Functions of and Relationship between Scientific Theories and Laws

This aspect of NOS was the most confusing aspect for the participants both before and after the instruction. At the beginning of the study, almost all of the participants (95 per cent) and, at the conclusion of the study, half, did not demonstrate informed views of the nature of theories and laws. Ideas related to this aspect of NOS were observed to be highly resistant to change with instruction. Most of the participants believed that there is a hierarchical relationship between scientific theories and laws. As can be seen in the following illustrative quotations, they expressed the view that with supportive experiments, evidence and with growing consensus among scientists, theories would become laws:

> *If a hypothesis is verified, it [the hypothesis] is accepted as a theory. If this theory is accepted by all scientists, it becomes a law. For example, the law of gravity.* [Item-5]. [Q_{pre}-26]

A scientific theory has not been completely proven. If a theory is accepted by everybody and is completely proven, a scientific law forms. [Item-5]. [Q_{pre}-17]

Such participants seem to view the difference between a law and a theory as a degree of proof (Akerson et al., 2000). A large majority perceived scientific laws as the ultimate form of scientific knowledge that was absolute and not amenable to change in the future

Analysis of a McNemar's test indicated statistically-significant changes from pre- to post-instruction in participants' views (n = 39, $p<0.001$). At the beginning of the study, only one PST and at the conclusion of the study half of the PSTs demonstrated informed views about the nature and relationships of scientific theories and laws. Such PSTs became aware that scientific theories and laws are different kinds of knowledge and one does not become the other (McComas, 1998):

There are differences between scientific theories and laws. On the one hand, laws try to describe observable data; on the other hand, theories try to explain observable data. For example, Mendel's law and the chromosome theory are proposed in different times. First Mendel's law and later the [chromosome] theory are developed. Another example is that Boyle's law is proposed first and then kinetic molecular theory is proposed after a long period of time. [Item-5]. [Q_{post}-07]

Inference and Theoretical Entities in Science

At the beginning of the study, 30 per cent and at the conclusion 13 per cent of the participants demonstrated naive views on the distinction between observation and inference. Their beliefs mainly relied on direct evidence and most of them equated knowing with seeing. They did not perceive that scientific knowledge might also be produced through indirect evidence or inferences. As evident in the following quotations, most of them noted that scientists are certain about atomic structure because they have observed the structure of atoms using, for example, high-powered electron microscopes. They believed that an atom looked exactly like the model itself.

Since we have microscopes that enable us to see the structure of the atom, scientists are quite sure about the structure of the atom. [Item-6]. [Q_{pre}-16]

Researcher: Let us assume that there is a mirror and we are looking through it. This mirror shows you exactly what it sees. So do you think the relationship between a model and the reality is the same?
ST: I do not know whether it is the same. When I look through the mirror, I can see myself virtual. I can exactly see all parts of my body the same. So, a mirror just reflects all these things.
Researcher: So, do you think reality and the model of the atom are the same? Do you think this model reflects the reality?
ST: In my opinion, it reflects….it reflects.
Researcher: In that case, can we say that this [model] is exactly the same as reality?
ST: We can say that this [model] is exactly the same as reality.
Researcher: In other words, you are saying that models are the copy of reality.
ST: [Using facial expression by saying yes]. [Item-6]. [I_{pre}-29]

At the conclusion of the study, changes were evident in the views of participants regarding the notion of inference and inferential entities. Analysis of a McNemar's test indicated statistically-significant changes from pre- to post-instruction in participants' views (n = 26, $p<0.05$). Thirty-eight per cent of the participants at the beginning and 75 per cent at the end of the study demonstrated informed views of the inferential nature of scientific knowledge. As evident in the following representative quotation, they were aware of the differences between observation and inferences, and indicated that atomic structure is a model constructed through experimentation and inference.

> *In order to verify their theories, scientists make inferences based on experiments… For example, when Rutherford carried out his studies by sending positive beams into lead plate, he discovered that some beams passed through the plate, but some others reflected. From these experiments, he proposed his atom model. Based on this sort of indirect observations, the atom model is constituted.* [Item-6]. [Q_{post}-20]

The Subjective or Theory-Laden Nature of Scientific Knowledge

Prior to the instruction, 40 per cent and after the instruction 8 per cent of the PSTs did not recognise the role that scientists' background knowledge, training, beliefs, biases and assumptions play in generating and supporting claims. They believed that science is an objective domain and that is why it is different from other disciplines such as religion. They argued that scientists were objective in conducting any scientific research:

> *In other disciplines, there is not a truth that can be proven. In those disciplines, views can be different from person to person. However, in science truth is a truth for everybody. It can be proven in any way.* [Item-1]…*Science is universal. Science cannot be different in terms of social and political values. It* [science] *must also be the same in the other parts of the world.* [Item-9]. [Q_{pre}-16]

The number of PSTs with informed views of the theory-laden NOS increased from pre- to post-instruction. Analysis of a McNemar's test indicated statistically-significant changes from pre- to post-instruction in participants' views (n = 30, p<0.001). Prior to the instruction, about 38 per cent and after the instruction about 83 per cent of the PSTs explicated informed views of the theory-laden NOS. In general, these participants recognised that scientists' educational backgrounds, personal experiences, beliefs, biases, social commitments and basic guiding assumptions (for example, the questions they ask, the methodologies they use and the data they collect) as well as other human elements and worldviews, influence the ways in which they interpret any (empirical) evidence, and generate and support scientific claims (Abd-El-Khalick & Lederman, 2000b; Akerson et al., 2009; Irzik & Nola, 2011). Here is a PST's response to the dinosaur extinction controversy question in the VNOS-C questionnaire:

> *Individual differences can explain this situation. Scientists perceived and interpreted differently: their point of views, the scientific method that they used, the environment-culture that they lived in, their ways of thinking, their logical inferences, their faith, their lives (experiences), and the knowledge that they have are different.* [Item-8]. [Q_{post}-31]

The Creative and Imaginative Nature of Scientific Knowledge

At the beginning of the study, 40 per cent of the PSTs and at the end 25 per cent expressed naive views regarding the creative and imaginative nature of scientific knowledge. While most PSTs agreed that scientists use creativity and imagination during their investigations, they believed that this involvement was limited to certain stages in scientific investigation. For them, creativity and imagination in science mostly occurred during planning and designing an investigation. The following excerpts exemplify this case:

... Science is objective. [Item-1]*... They [creativity and imagination] are used during planning and designing. Because, after these stages they [scientists] must be objective.* [Item-10]. [Q_{pre}-22].

Scientists use their creativity and imagination during planning and designing and slightly use them during data collection; however, it would not be appropriate to use them after data collection. That would affect the objectivity of scientific knowledge. [Item-10]. [Q_{pre}-26].

This finding closely resembles the findings of Khishfe and Abd-El-Khalick (2002) and Abd-El-Khalick (2005) in that students (Khishfe & Abd-El-Khalick, 2002) and pre-service teachers (Abd-El-Khalick, 2005) believed that creativity and imagination cannot be used in science since that would distort the objectivity of science. In a similar vein, many participants did not seem to perceive that scientific knowledge is the product of human imagination and creativity. While answering Items 6 and 8 (Lederman et al., 2002), they stated that scientists would learn about the atom and dinosaurs only by actually seeing them. For instance, as mentioned earlier, they simply indicated that scientists are very certain of the structure of the atom because they can see the structure with high-powered microscopes.

Analysis of a McNemar's test indicated no statistically significant changes from pre- to post-instruction in participants' views (n = 39, $p>0.05$). Sixty per cent of the PSTs at the beginning and 73 per cent at the end of the study had informed views about the role of creativity and imagination in generating scientific knowledge. They stated that scientists would use their creativity and imagination during all phases of their scientific investigation and that scientific knowledge is the product of human imagination and creativity. The following excerpt exemplifies such cases:

From my point of view, creativity and imaginations are used in all stages of scientific inquiry and in [everyday] lives. ...Darwin put his observations together in a creative way to establish the fundamentals of the theory of evolution. [Item-10]. [Q_{post}-31]

Social and Cultural Influences

At the beginning of the study, 75 per cent, and at the conclusion, 20 per cent of the PSTs demonstrated naive views about the social and cultural embeddedness of science. As quoted below, these participants believed in the universality of science and rejected a role for social and cultural factors in science:

[Science is] universal... Because scientific knowledge does not change from person to person or from place to place. [Item-10]. [Q_{post}-25]

Science is universal. It is not in the monopoly of one group. Today, knowledge that is found by a Japanese scientist interests all of us. Science is objective. A religious person cannot deny the theory of evolution. We must talk based on scientific evidence. [Item-10]. [Q_{post}-05]

Analysis of a McNemar's test indicated statistically-significant changes from pre- to post-instruction in participants' views (n = 37, $p<0.001$). Twenty per cent of the PSTs at the beginning and 75 per cent at the end of the study had informed views about the social and cultural embeddedness of science. These participants argued that scientific knowledge is affected by the social and cultural context in which it is produced and developed:

> *In my opinion, science cannot be universal. Science reflects social and cultural values. For example, Aristotle made the empirical classifications based on his belief…or from today's context; there are different views among different societies about the issue of abortion… [While] in some countries [and/or] societies it [abortion] is prohibited, in some others it is left to any individual's will [decision]. Abortion is the same abortion; the way to do it is the same. However, the interpretation of this among different societies is different.* [Item-9]. [Q_{post}-05] …*When science is put into practice, it is affected by cultural values.* [Item-9]. [I_{post}-05].

PSTs' views on the Most/Least Effective Method of Learning about NOS

As mentioned earlier, there was a question in the TR Questionnaire that asked 'What were the most and least effective methods for you to learn ideas about nature of science throughout the *STiS-II* course?' When the PSTs were asked to express the most and least effective method of learning about NOS, their views showed a significant range. In some cases, the total number of choices/subcategories may exceed the total number of the participants because some PSTs identified more than one method as the most or least effective for learning about NOS. Almost half (46 per cent) attributed their advancement in NOS, first and foremost, to their small-scale research projects (Strategy 2). Discussion and critical analysis of research papers (Strategy 1 – 27 per cent), reading and discussing papers related to NOS (Strategy 4 – 21 per cent), and lecturer-led presentations/activities related to NOS (Strategy 3 – 11 per cent) were also considered to be among the most effective methods of learning about NOS. Seventeen per cent of the PST saw all of these activities (Strategies 1 to 8) together as the most effective methods of learning about NOS. The following excerpt from an interview exemplifies this view:

> *Researcher: What was the most and least effective method of learning about NOS during this course?*
> *ST: Actually all of them [were effective], because all of them were like a whole. Articles, book sections, presentations, discussions….If one is missing there would not be the other. If we exclude discussion sections, just presentation would not be that effective. The teacher guided [us] through discussions and through articles related to NOS. I believe that wherever questioning [inquiry] takes place, effective learning occurs.* [Q7]. [Interview].

Reading and discussing papers related to NOS (Strategy 4 - 27 per cent), discussion and critical analysis of research papers (Strategy 1 - 19 per cent), and lecturer-led presentations/activities related to NOS (Strategy 3 – 11 per cent) were seen as being among least effective methods of learning about NOS during the *STiS II* course. Typical responses were as follows:

> *Reading articles sometimes can be boring*
> *Sometimes discussions were off the point that is why I think discussions were not effective.*
> *I found our discussions unnecessary, because sometimes nonsense views came and that made me surprised.*

Discussion and Educational Implications

This paper discusses the outcomes of a course that integrates an explicit-reflective NOS instruction (Abd-El-Khalick, 2005; Akerson et al., 2000) into the teachers-as-researchers approach (Cakmakci, 2009; Cochran-Smith & Lytle, 1999; Roth, 2007; van Zee, 1998) to improve PSTs' conceptions of NOS. Nonetheless, this study did not simply look at the outcomes of teaching; it also discussed the actual design of teaching and the key issues that underpin the nature of teaching and learning about NOS. The proposed teaching in this study had eight crucial strategies (Strategies 1-8) that complemented each other in addressing the NOS aspects. The key issues underpinning the design of each were discussed in the methodology section. Research shows that both students' and teachers' understanding about NOS depends to some extent on the contextual features of the activity in which they are engaged (Clough, 2006; Guerra-Ramos et al., 2010; Leach et al. 2003). Therefore, the activities aimed at reinforcing PSTs' ideas about NOS and at helping them to encounter specific ideas multiple times and in a variety of contexts. For example, teaching about the nature of theories and laws mentioned on some examples from the history of science (Lederman & Abd-El-Khalick, 1998) (Strategy 3). In addition, while a group of PSTs presented their study on '*teachers' views on the theory of evolution and on the way the new Turkish Science and Technology Curriculum addresses this concept*' (Strategy 6) (see Table 1), the function of and relationship between scientific theories and laws were also discussed. This activity was used to reinforce participants' understandings of this NOS aspect. As Mercer (1995, 19) pointed out, learners 'need to use new knowledge themselves, under different conditions, if they are to make the new knowledge their own'. Consequently, the results indicate that the combination of these eight strategies caused some desirable changes in the participants' NOS views and in most cases these changes were statistically significant. At the completion of the course, many participants demonstrated an ability to articulate fairly detailed descriptions of all targeted aspects of NOS.

These results corroborate findings of other studies (Abd-El-Khalick & Lederman, 2000a; Akerson et al., 2000; Akerson et al., 2009; Bell et al., 2003; Clough, 2006; Leach et al., 2003; Schwartz et al., 2004), showing that crucial aspects of NOS can be taught effectively through brief teaching strategies that are well designed and contextualised. Which activity in the course led to the most effective learning of NOS? When the PSTs were asked to identify the most and least effective method of learning about NOS, actually conducting a small-scale educational research project was seen by almost half of the participants (46 per cent) as the most effective strategy for learning about essential aspects of NOS (Strategy 2). This educational research experience helped the participants to understand the relationships between their research and knowledge generation in science. From a situated cognition perspective (Brown et al., 1989; Lave & Wenger, 1991), the educational research setting provided a context in which participants could reflect on the NOS aspects, but explicit instruction and the role of the lecturer as a mediator was crucial in PSTs' understanding about NOS (see Figure 1). In other words, central to this process was not only the conduct of an educational research project itself, but also guided participation (Rogoff, 1990) and reflection, which contributed to the PSTs' understanding of NOS (Bell et al., 2003; Grindstaff & Richmond, 2008). It should be noted that without sufficient guidance from the lecturer, it is possible for participants to misunderstand key features of theoretical and methodological aspects of the research project they are carrying out (Cakmakci, 2009). The significance of this study is that carrying out an educational research project with the incorporation of an explicit-reflective instructional model seems to be a promising avenue for improving PSTs' ideas about NOS. Teacher preparation and professional development programs should, therefore, promote the value of educational research and prepare teachers as researchers. The teaching resources and results of the present study might be used to inform the design of these programs in the way Dillon, Sissling, Watson & Duschl (2002) started to do for science teacher professional development programs. During this research process, the lecturer and PSTs' relationships is important and both parties can gain academically: 'Some parts of these gains might be seen as aspects of 'professional socialization' in which apprentices in any field begin to absorb its norms, practices, as well as the knowledge [and skills] required to be proficient practitioners' (Seymour et al., 2004, 531). Investigation of the nature of such professional socialisation (Akerson et al., 2009; Dillon et al., 2002; Lave & Wenger, 1991) in the context of engagement with a research project and its influences on ideas about NOS could be a direction for future research. It would also be interesting to investigate the impact of such studies on teacher practice and/or student learning in schools. This study suggests that both context and pedagogy play crucial roles in teaching about NOS. I believe that the framework provided in Figure 1 has possible implications for planning teaching in that it would permit the organisation of the various considerations that need to be taken into account during teaching about NOS (Clough, 2006). Accordingly, characteristics of these three continua (instruction, context and assessment) depicted in Figure 1 should be acknowledged during pre-service and in-service teacher training programs.

Acknowledgements

The author would like to thank Dr. Jacqueline Bell for her valuable comments on the paper and Dr. Yalcin Yalaki for his help in the data analysis process. The author would also like to thank the anonymous reviewers for their constructive criticisms and suggestions.

References

Abd-El-Khalick, F. (2005). Developing deeper understandings of nature of science: the impact of a philosophy of science course on preservice science teachers' views and instructional planning. *International Journal of Science Education*, *21*(1), 15-41.

Abd-El-Khalick, F. & Lederman, N. G. (2000a). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science Education*, *22*(7), 665-702.

Abd-El-Khalick, F. & Lederman, N. G. (2000b). The influence of history of science courses on students' views on nature of science. *Journal of Research in Science Teaching*, *37*(10), 1057-1059.

Akerson, V. L., Abd-El-Khalick, F. & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching*, *37*(4), 295-317.

Akerson, V. L., Cullen, T.A. & Hanson, D. L. (2009). Fostering a community of practice through a professional development program to improve elementary teachers' views of nature of science and teaching practice. *Journal of Research in Science Teaching*, *46*(10), 1090-1113.

Allchin, D. (2011). Evaluating knowledge of the nature of (whole) science. *Science Education, 95*(3), 518-542.

Alters, B.J. (1997). Whose nature of science? *Journal of Research in Science Teaching*, *34*(1), 39-55.

American Association for the Advancement of Science (AAAS). (1995). *Science for all Americans*. New York: Oxford University Press.

Aydeniz, M., Baksa, K., & Skinner, J. (2011). Understanding the impact of an apprenticeship-based authentic scientific research program on high school students' understanding of scientific inquiry. *Journal of Science Education and Technology, 20*(4), 403-421.

Bagci-Kilic, G. (2003). The Third International Mathematics and Science Study (TIMSS): Science teaching, scientific research and nature of science (in Turkish). *Ilkogretim-Online*, *2*(1), 42-51.

Baker, D.R. (2004). Focus on scientific literacy: The role of writing and speaking in the construction of scientific knowledge. *Eurasian Journal of Educational Research*, *16*, 1-7.

Bell, R., Blair, L., Lederman, N.G. & Crawford, B. (2003). Just do it? Impact of a science apprenticeship on high school students' understandings of the nature of science and scientific inquiry. *Journal of Research in Science Teaching*, *40*(5), 487-509.

Bennett, J. & Campbell, B. (2002). First steps in educational research: the experience of student teachers. *School Science Review*, *84*(307), 49–59.

Brickhouse, N. W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education*, *41*(3), 53-62.

Brown, J.S., Collins, A. & Duguid, P (1989). Situated cognition and the culture of learning. *Educational Researcher*, *18*(l), 32-42.

Cakmakci, G. (2009). Preparing teachers as researchers: Evaluating the quality of research reports prepared by student teachers. *Eurasian Journal of Educational Research*, *35*, 39-56.

Clough, M.P. (2006). Learners' responses to the demands of conceptual change: Considerations for effective nature of science instruction. *Science Education*, *15*, 463-494.

Clough, M.P., & Olson, J.K. (2008). Teaching and assessing the nature of science: An introduction. *Science & Education*, *17*, 143-145.

Cobern, W. W., & Loving, C. C. (2001). Defining 'science' in a multicultural world: Implications science education. *Science Education*, *85*(1), 50-67.

Cochran-Smith, M. & Lytle, S. (1999). The teacher research movement: A decade later. *Educational Researcher*, *28*, 15-25.

Collins, A., Brown, J. S. & Holum, A. (1991). Cognitive apprenticeship: making thinking visible. *American Educator*, *15*(3), 6-11, 38-46.

Demircioglu, I. H. (2008). Learning how to conduct educational research in teacher education: A Turkish perspective. *Australian Journal of Teacher Education, 33*(1), 1-17.

Dillon, J., Sissling, S., Watson, R. & Duschl, R. (2002). Science teachers as researchers - a model for professional development. *School Science Review*, *84*(307), 43-4-46.

Driver, R., Leach, J., Millar, R. & Scott, P. (1996). *Young people's images of science.* Buckingham, UK: Open University Press.

Duschl, R. A. (2000). Making the nature of science explicit. In R. Millar, J. Leach, & J. Osborne (eds.) Improving science education: The contribution of research. Buckingham, UK: Open University Press, 187-206.

Ericsson, K. A. & Simon, H. A. (1993). *Protocol analysis: Verbal reports as data*. Cambridge, MA: MIT Press.

Grindstaff, K. & Richmond, G. (2008). Learners' perceptions of the role of peers in a research experience: Implications for the apprenticeship process, scientific inquiry, and collaborative work. *Journal of Research in Science Teaching*, *45*(2), 251-271.

Guerra-Ramos, M.T., Ryder, J. & Leach, J. (2010). Ideas about the nature of science in pedagogically relevant contexts: Insights from a situated perspective of primary teachers' knowledge. *Science Education*, *94*(2), 282-307.

Hanuscin, D. L., Lee, M. H. & Akerson, V. L. (2011). Elementary teachers' pedagogical content knowledge for teaching the nature of science. *Science Education*, *95*(1), 145-167.

Haukoos, G.D. & Penick, J.E. (1985). The effects of classroom climate on college science students: a replication study. *Journal of Research in Science Teaching*, *22*(2), 163-168.

Irez, S. (2006). Are we prepared?: An assessment of preservice science teacher educators' beliefs about nature of science. *Science Education*, *90*(6), 1113-1143.

Irzik, G. & Nola, R. (2011). A family resemblance approach to the nature of science for science education. *Science & Education*, *20*(7-8), 591-607.

Khishfe, R. & Abd-El-Khalick, F. (2002). The influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching*, *39*(7), 551-578.

Kucuk, M. (2008). Improving preservice elementary teachers' views of the nature of science using explicit reflective teaching in a science, technology and society course. *Australian Journal of Teacher Education*, *33*(2), 16-40.

Lave, J. & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, Cambridge University Press.

Leach, J. & Scott, P. (2002). Designing and evaluating science teaching sequence: An approach drawing upon the concept of learning demand and a social constructivist perspective on learning. *Studies in Science Education*, *38*, 115-142.

Leach, J., Hind, A. & Ryder, J. (2003). Designing and evaluating short teaching strategy about the epistemology of science in high school classroom. *Science Education*, *87*(6), 831-848.

Lederman, N.G. (2007). Nature of science: Past, present and future. In S.A. Abell & N.G. Lederman (eds.) Handbook of research on science education. Mahwah, NJ: Lawrence Erlbaum Associates**,** 831-879.

Lederman, N.G. & Abd-El-Khalick, F. (1998). Avoiding de-natured science: Activities that promote understandings of the nature of science. In W.F. McComas (ed.). *The Nature of Science in Science Education: Rationales and Strategies*. Dordrecht: Kluwer, 83-126.

Lederman, N.G., Abd-El-Khalick, F., Bell, R.L. & Schwartz, R.S. (2002). Views of the nature of science questionnaire: Toward valid and meaningful assessment of learner's conceptions of the nature of science. *Journal of Research in Science Teaching*, *39*(6), 497-521.

McComas,W. F. (1998). The principal elements of the nature of science: Dispelling the myths. In W. F. McComas (ed.). *The Nature of Science in Science Education: Rationales and Strategies* (pp. 53-70). Dordrecht: Kluwer, 53-70.

MEB (Turkish Ministry of National Education) (2005). *Science and Technology Curriculum*. Retrieved 10 September 2010 from http://ttkb.meb.gov.tr/ogretmen.

Mercer, N. (1995). *The guided construction of knowledge: Talk amongst teachers and learners*. Clevedon, UK: Multilingual Matters.

Millar, R. (2003). Communicating your research to others. In D. Krnel (ed.). Proceedings of the Sixth ESERA (European Science Education Research Association) Summer School 2002. Ljubljana: University of Ljubljana, 97-104.

Millar, R. (2006). Twenty first century science: Insights from the design and implementation of a scientific literacy approach in school science. *International Journal of Science Education*, *28*(13), 1499-1521.

Mortimer, E. F. & Scott, P. H. (2003). *Meaning making in secondary science classrooms*. Maidenhead, UK: Open University Press.

National Science Teachers Association (2000). *NSTA position statement on the nature of science*. Retrieved 12 January 2012 from http://www.nsta.org/about/positions/natureofscience.aspx.

Nuffield Twenty First Century Science (2007). *Twenty first century science resources*. Retrieved 11 December 2009 from http://www.21stcenturyscience.org.

Osborne, J., Ratcliffe, M., Collins, S., Millar, R. & Duschl, R. (2003). What ‘ideas-about science’ should be taught in school science? A delphi study of the ‘expert’ community. *Journal of Research in Science Teaching*, *40*(7), 692-720.
Rogoff, B. (1990). *Apprenticeship in thinking*: Cognitive development in social context. New York: Oxford University Press.
Roth, K.J. (2007). Science teachers as researchers. In S. K. Abell & N. G. Lederman (eds.) *Handbook of research on science education*. Mahwah, NJ: Lawrence Erlbaum Associates**,** 1205-1259.
Rudolph, J. L. (2000). Reconsidering the ‘nature of science’ as a curriculum component. *Journal of Curriculum Studies*, *32*(3), 403-419.
Sadler, T. D. (2009). Situated learning in science education: Socio-scientific issues as contexts for practice. *Studies in Science Education*, *45*(1), 1-42.
Sadler, T.D., Burgin, S., McKinney, L. & Ponjuan, L. (2010). Learning science through research apprenticeships: A critical review of the literature. *Journal of Research in Science Teaching*, *47*(3), 235-256.
Schwartz, R. S. & Crawford, B. A. (2006). Authentic scientific inquiry as a context for teaching nature of science: Identifying critical elements for success. In L. Flick & N. Lederman (eds.) *Scientific inquiry and nature of science: Implications for teaching, learning, and teacher education*. Dordrecht: Kluwer, 331-355.
Schwartz, R. S., Lederman, N. G. & Crawford, B. A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education*, *88*(4), 610-645.
Scott, P., Leach, J., Hind, A. & Lewis, J. (2006). Designing research evidence-informed teaching strategy. In R. Millar, J. Leach, J. Osborne & M. Ratcliffe (eds.) *Improving subject teaching: lessons from research in science education.* London, UK: Routledge, 60-78.
Seker, H. & Welsh, L. C. (2006). The use of history of mechanics in teaching motion and force units. *Science & Education*, *15*, 55-89.
Seymour, E., Hunter, A. B., Laursen, S. L. & Deantoni, T. (2004). Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study. *Science Education*, *88*(4), 493-534.
Shulman, L. S. (1986). Those who understand: knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14.
Sozbilir, M. (2007). First steps in educational research: The views of Turkish chemistry and biology student teachers. *European Journal of Teacher Education*, *30*(1), 41-61.
Tasar, M.F. (2005). Probing preservice teachers' understandings of scientific knowledge by using a vignette in conjunction with a paper and pencil test. *Eurasia Journal of Mathematics, Science & Technology Education, 2*(1), 53-70.
Turkmen, L. (2006). Nature of scientific knowledge and science-technology literacy. In M. Bahar (ed.). *Science and technology teaching*. Ankara: PegemA Yayincilik, 34-58.
van Zee, E. H. (1998). Preparing teachers as researchers in course on methods of teaching sciences. *Journal of Research in Science Teaching*, *35*(7), 791-809.
Yalaki, Y. & Cakmakci, G. (2010). A conversation with Michael R. Matthews: The contribution of history and philosophy of science to science teaching and research*.* *Eurasia Journal of Mathematics, Science and Technology Education*, *6*(4), 287-309
Yildirim, C. (2005). *Philosophy of Science*. Tenth ed. Ankara, Turkey: Remzi Kitabevi, 15-23.