

A Study Toward Teaching The Nature of Science to Pre-Service Teachers ¹

Serkan SEVİM¹ , Canay Altındağ PEKBAY²

¹ Assist.Prof.Dr., Pamukkale University, Elementary Education Department, Science Teacher Education Program, Denizli- TURKEY

² Research Assistant, Bülent Ecevit University, Ereğli Education Faculty, Elementary Education Department, Zonguldak- TURKEY

Alındı: 03.05.2011

Düzeltildi: 25.04.2012

Kabul Edildi: 26.07.2012

Orijinal Yayın Dili Türkçedir (v.9, n.3, Eylül 2012, ss.207-227)

ÖZET

This study investigated the influence of the nature of science teaching activities, based on explicit-reflective inquiry oriented approach on pre-service teachers' nature of science concepts. This study is interpretive in nature because it focused on the meanings that participant ascribed to the emphasize aspects of nature of science. Twelve teaching activities based on the empirical, tentative, inferential, creative and imaginative, subjective, socially and culturally and relationships between scientific theories and laws nature of scientific knowledge were designed and implemented to a group of 36 pre-service teachers. Study was implemented in Science Teaching Laboratory Application-I lesson. In lesson, participants determined a problem case and studied on this problem like a scientist. Besides, explicit-reflective teaching activities were implemented to participants. After each of activity, pre-service teachers wrote reflective notes. Data was gathered by a pre-post "nature of science questionnaire", semi structured interviews, and also reflective notes for each of the activity by participants. Each pre-service teachers' pre and post nature of science profiles were constructed and compared, thus, effect of the activities on the participants was determined. While participants' profiles were constructed, the data by categorizing each participants' views of the seven emphasized aspects of NOS into "adequate", "variable" and "poor". In order to learn about the effects of the explicit-reflective nature of science teaching activities on views on scientific knowledge, paired t test was used. From the data, it was concluded that pre-service teachers had uncertain views about the nature of science at the beginning, however after the intervention; pre-service teachers had very informed views about it. Especially, there was a significant change in pre-service teachers' views on four aspects of the nature of science; tentative, relationships between scientific theories and laws, creative of scientific knowledge and inference of nature of science. It is suggested that developing informed conceptions of the nature of science for pre-service teachers is a cognitive instructional outcome that requires an explicit-reflective instructional approach.

Anahtar Kelimeler: Teaching the Nature of Science, Explicit-Reflective Approach, Views about Scientific Knowledge.

¹ This study is enlarged and revised edition of an oral notification which is presented "6th International Conference on Education (ICE)" in Samos, Greece.



INTRODUCTION

Today, efforts to reform science education emphasis on the development of accurate understandings about the nature of science (Bell, Matkins and Gansneder, 2011). To qualify as scientific literacy members of the community, need to have sufficient understanding of the nature of science (McComas, 1998). Scientific literacy is defined as what is the knowledge of science, that is, knowledge of the nature of science (Lederman, 1998; McComas, Clough and Almazro, 2002; Shamos, 1995). There is no one common definition of NOS among science historian, philosopher and educators. Typically, the NOS has been used to refer to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992). Moreover, despite continuing disagreements about a specific definition for NOS, at a certain level of generality and within a certain period of time, there is a "shared wisdom" about NOS (Abd-El-Khalick and Lederman, 2000; Bell, Lederman and Abd-El-Khalick, 2000; Lederman, 1992; Lederman, Abd-El-Khalick, Bell and Schwartz, 2002). In literature, the main of nature of science' features (Cartier, 2000; Lederman et al., 2002; McComas, 1998):

- Science is as a way of knowing,
- Scientific knowledge is tentative,
- Scientific knowledge is empirical,
- Scientists are subjective,
- Scientific knowledge is partly the product of human inference, imagination, and creativity,
- Scientific knowledge is socially and culturally embedded.
- Observation and inference are different,
- The lack of a universal recipe-like method for doing science,
- The functions of and relationships between scientific theories and laws.

Research has consistently shown that students', pre-service teachers' and teachers' views of NOS are not consistent with contemporary conceptions of the scientific endeavor (Abd-El-Khalick, Waters and Le, 2008; Blanco and Niaz, 1997; Briscoe, 1991; Irez, 2006; McComas, 2003; Ryan and Aikenhead, 1992).

There are many attempts for developing students', pre-service teachers' and teachers' views of NOS (Abd-El-Khalick and Akerson, 2004; Akerson et al., 2000; Irwin, 2000). For this, Driver et al. (1996) suggest five reasons: (a) NOS help that person to understand science, the products of science and methods encountered in daily life (b) help that person to participate in discussions about science, (c) provide that person appreciation to scientific culture (d) provide that person understand norms of scientific community (e) help that science subject area is learned more efficient.

Teaching the NOS to students has long been a goal of science educators (Abd-El-Khalick and Lederman, 1998; Driver et al., 1996; Hogan, 2000; Lederman, 1992; Reif and Larkin, 1991). Numerous attempts have been undertaken to enhance learners' views of NOS. These attempts can be categorized under three general approaches: (a) explicit-reflective, (b) implicit and (c) historical approach (Abd-El-Khalick and Lederman, 2000; Khishfe and Abd-El-Khalick, 2002).

History of Science Cases for High Schools (HOSC) (Klopfer and Watson, 1957) and the Harvard Project Physics (HPP) course (Rutherford et al., 1970) are two notable examples of curricula that adopted the historical approach. A study undertaken by Solomon et al. (1992) serves to illustrate the historical approach. Solomon et al. aimed to

document how learning science through history of science might influence students' views of the tentative nature of scientific ideas and their relationship to the social and cultural contexts within which they were developed. Although participants' images of scientists and views regarding why scientists subscribe to different theories remained virtually unchanged, Solomon et al. (1992) noted some favorable changes in their participants' views at the conclusion of the study.

Whereas Klopfer and Cooley (1963) reported favorable changes in learners' views, Welch and Walberg (1972) reported that historically oriented science instruction failed to influence students' conceptions of NOS favorably.

Most of the 1960s and 1970s curricula, such as the Physical Science Study Curriculum (PSSC) and the Biological Sciences Curriculum Study (BSCS), adopted implicit approach (Khishfe and Abd-El-Khalick, 2002). However, research has consistently shown that the implicit approach was not effective in helping students to develop informed NOS views (Lederman, 1992; Meichtry, 1992; Moss et al., 1998; Tamir, 1972; Trent, 1965). Trent (1965) reported that the inquiry-oriented PSSC curriculum was not more effective than a traditional textbook-centered curriculum in enhancing students' NOS views. Meichtry (1992) investigated the effect of the BSCS program on middle school students' understandings of the developmental, testable, creative, and unified NOS. The ineffectiveness of the implicit approach in enhancing students' NOS views could be attributed to an underlying assumption: namely, that student would automatically develop better NOS conceptions as a by-product of engagement in science-based inquiry activities or science process skills instruction (Khishfe and Abd-El-Khalick, 2002).

The explicit-reflective approach advances that the goal of improving learners' NOS views "should be planned for instead of being anticipated as a side effect or secondary product" of varying approaches to science teaching (Abd-El-Khalick and Lederman, 2000). Thus, NOS aspects should be taught to learners explicitly (Khishfe and Abd-El-Khalick, 2002). Some researchers used explicit-reflective approach for enhance students' views of NOS (Carey et al., 1989; Khishfe and Abd-El-Khalick, 2002; Fishwild, 2005; Khishfe, 2008). Some researchers used explicit-reflective approach for enhance teachers' views of NOS (Abd-El-Khalick et al., 1998; Lederman, 1999; Akerson et al., 2000; Abd-El-Khalick, 2001; Akerson and Hanuscin, 2007). Akerson et al. (2000), Bianchini and Colburn (2000), Abd-El-Khalick and Akerson (2004), McDonald (2008) used this approach for enhance pre-service teachers' views of NOS.

Also three approaches are useful for enhance students', teachers' and pre-service teachers' views of NOS (Abd-El-Khalick and Lederman, 2000; Schwartz et al., 2004). However, evidence suggests that an explicit-reflective approach could substantially improve learners' NOS views (Abd-El-Khalick and Lederman, 2000; Bell et al., 2011; Khishfe and Abd-El-Khalick, 2002; McDonald, 2010).

NOS teaching; historical, implicit and explicit-reflective approach were used for many years. But literature is examined, in 2000s and years before 2000s the use of historical and implicit approaches have come to the fore (Tamir, 1972; Meichtry, 1992; Solomon et al., 1992; Abd-El-Khalick and Lederman, 2000; Irwin, 2000). In recent years, explicit-reflective approach has used more common (Khishfe and Abd-El-Khalick, 2002; Abd-El-Khalick and Akerson, 2004; Fishwild, 2005; Akerson and Hanuscin, 2007; Khishfe, 2008). Between the use of explicit-reflective approach and pre-service teachers' learning of NOS is not too clear. When looked at the research, this approach is usually used with students (Khishfe and Abd-El-Khalick, 2002; Fishwild, 2005; Khishfe, 2008).

Primarily, teachers' understandings of NOS should be provided. If teachers have a misunderstanding about NOS, they can transfer this mistake to students. Thus, the

influence of explicit-reflective approach on pre-service teachers' NOS concepts is assessed.

The aim of study

This study investigated the influence of the nature of science teaching activities based on explicit-reflective approach on pre-service teachers' nature of science concepts.

MATERIALS AND METHODS

The present study was interpretive in nature (Strauss and Corbin, 1990) and focuses on the meanings that participants ascribed to the emphasized NOS aspects. The data collection was continuous and spanned nearly a three months period in which participants were enrolled in the Science Teaching Laboratory Application-I lesson.

Participants

Thirty six pre-service science teachers (16 female and 20 male) who continue their education in Pamukkale University, Education Faculty and are enrolled Science Teaching Laboratory Application-I lesson participated in the study.

Context of the study: Science Teaching Laboratory Application-I lesson

I lecture the lesson which was a three credit/hours optional course. The classes were held weekly in three-hour blocks throughout the three-month period. The course aimed at helping pre-service science teachers to develop deeper understandings of NOS aspects. In the content of the lesson, pre-service teachers were provided with some activities that were specifically designed to enhance learners' views of some aspects of NOS. Those activities were taken from literature (Lederman and Abd-El-Khalick, 1998). And Küçük (2006) translated those activities from Turkish. These aspects of NOS are; empirical, tentative, inferential, creative and imaginative, subjective, socially and culturally and relationships between scientific theories and laws. Twelve NOS activities were implemented in lectures. These were; the cubes, tricky tracks, the aging teacher, young? or old?, water generator, paper rolls, hypothesis boxes, perforated bottle, lets find it, what is in the box?, burning candles, and picture a scientist.

Each activity was followed by a whole-class discussion that aimed to explicitly highlight the target aspects of the NOS and involve pre-service teachers in active discourse concerning the presented ideas. In these discussions the instructor purposely supported pre-service teachers to make linkages between the activities implemented and scientists' real experiences toward developing scientific knowledge.

Data Collection Methods

An open-ended questionnaire in conjunction with semi-structured interviews was used to assess participants' views of the target aspects of NOS. All participants were administered the questionnaires before and at the conclusion of the study. In addition, fifteen participants were also selected for interviewing. The use of an open-ended questionnaire was intended to avoid the problems inherent in the use of standardized forced-choice paper and pencil NOS assessment instrument. These instruments are based on the problematic assumption that the meanings that respondents ascribe to an instrument items, and the reasons behind their choosing certain responses correspond to those of the instrument developers and/or researchers. Moreover, because they were of the forced-choice type, these instruments often end up imposing a certain view of NOS on respondent (Lederman et al., 1998). In contrast, open-ended items allow respondents to elucidate their own views regarding the target aspects of NOS and the reasons that underlie their views (Lederman, 1992).

The ten-item open-ended questionnaire used in the present study was previously used and validated by Lederman et al, (2002). The data was collected within three months in which the study was conducted. The data were collected using an open-ended questionnaire, “Views of the Nature of Science- Form C (VNOS-C)” (Lederman et al., 2002). This questionnaire was used to assess participants’ views of the NOS prior to and at the end of the study. The researcher, who was also responsible for the implementation phase of the teaching activities, also conducted semi-structured interviews with students enrolled in the course prior to and at the conclusion of the study. Interview findings were used to explore the validity of participants’ responses to the questionnaire items. The participants were provided with their pre/post instruction questionnaires during these interviews and they were asked to explain and elaborate on their responses. This method was used in several studies to assess subjects’ views related to NOS (Akerson et al., 2000; Akerson et al., 2006; Matkins et al., 2002). The interviews also aimed to generate in-depth profiles of participants’ NOS views. The interviews all lasted about 30 minutes and were audiotaped and transcribed for analysis.

Table 1: Research Design

Group (N:36)	First Tests	Application	Last Tests
	- Views of the Nature of Science- Form C -Interview	Nature of science teaching activities based on explicit-reflective approach	- Views of the Nature of Science- Form C -Interview

Data Analysis

Qualitative Data Analysis

In the context of this study first, before activities were applied, the NOS questionnaires and corresponding interview transcripts of the all participants were analyzed and participants’ pre profile were constructed and compared. In his process “constant comparative analysis” method was used. This method was also used for participants’ post profile. In addition to profiles, pre-service teachers’ views of NOS were examined as frequency and percent.

While participants’ profiles were constructed, the data by categorizing each participants’ views of the seven emphasized aspects of NOS into “adequate”, “variable” and “poor”. For example, if a participant responded that “*scientific theories change because there might be new evidence collected*” or “*theories change because of new evidence or reinterpretation of old evidence*” the response was coded as “adequate” view of tentative nature of scientific theories. If the participant responded that “theories will never change” then the response was coded as “poor” view of tentative nature of scientific theories. While participant produced adequate views some items, they didn’t produce adequate views all of the items as “variable” view of tentative nature of scientific theories. Finally, I compared pre-post profiles to assess changes in participants’ NOS views.

FINDINGS AND DISCUSSION

This section elucidates participants’ pre-instruction and post-instruction views on the targeted aspects of NOS. The number following a students’ response refers to an individual participant. Table 2 presents a summary of results from the study.

Pre– Post–Instruction NOS Views

Table 2: Percentage compare to pre-service teachers' pre-post profiles of NOS

N: 36	Tentative NOS	Empirical NOS	Subjective NOS	Creative and Imaginative NOS	Observations versus Inference	Social and cultural NOS	Relationships between Theories and Laws
	A V P	A V P	A V P	A V P	A V P	A V P	A V P
%pre	17 14 70	92 8 -	- 19 81	22 44 33	6 8 86	14 11 75	- 6 94
%post	42 58 -	100 - -	8 53 39	83 14 3	64 28 8	22 25 53	22 33 44

Table 2 shows that there was a substantial increase in participants who held adequate views of the target aspects of the NOS at the end of the study. There were observed changes in each aspect of the NOS targeted. However, the observed changes were not consistent across the investigated NOS aspects. For example, changes in participants' views were particularly pronounced with regard to the tentative NOS, creative and imaginative NOS, the distinction between observation and inference and the relationship between theory and law. Less pronounced changes in participants' views of science were empirical and subjective and the social and cultural NOS.

a) Tentative NOS

Table 3: Participants' pre-post test about tentative NOS

GROUP		Participants' Pre-test		Participants' Post-test	
		f	%	f	%
Tentative NOS	A	6	17	15	42
	V	5	14	21	58
	P	25	70	-	-

At the beginning of the study, the majority of the preservice teachers (70%) held also inadequate views of the tentative NOS. They all believed that scientific laws were proven and did not change. Many thought theories did change, but only because they changed into laws, or because of new technologies which allowed us to see things differently. At the conclusion of the study 42% of the student teachers stated more adequate views of the tentativeness of scientific knowledge. Students most often reported that the reason for a change in a scientific view was due to new evidence, and that creates a better explanation. The participants also expressed a view that all scientific knowledge was subject to change, and could change via a modification of current ideas, or the replacement of current ideas with ones based on better evidences.

The change in the participants' view about the tentative nature of science can be seen in the response given in the surveys. In the beginning of the study, D19 who had a poor view about the tentative nature of science could not answer the 1st 4th and the 5th questions. ,for the 1st question which was 'what does science mean? what separates science from other fields?' while answering this question as ;

"Science is the position of the systematically categorized information. Generally we are told that science came from religion. The things which are prohibited by religion, science researched religion can change, but science, can not." At the end of the study s/he answered the same question as ;

“Science is the process of assembling experiments and ideas together, and reveal truth and reality. Science questions it’s own truths. so, there is no certainty in science. It can change. Because science is skeptical.”

To the 4th question which was ‘after scientists develop a scientific theory, can that theory change? Give an example.’ While s/he answering as;

“For instance there was the evolution theory. It remained as theory many people worked hard bur they could not reach anything. It remained as a theory.” at the end of the study, s/he answered the same question as:

“It can change. Because science is skeptical. IT investigates the complete truthiness in life

To the 5th question which was: “Is there a difference between scientific theory and scientific law? Give an example.” The participant’s answer was:

“There is a difference between theories and laws. The theory, I mean, even if a number of people think about the subject, there are more or less differences. But in law, scientists find the same things, that is why it became a law, after all. It became definite. Thus, the difference of the law from the theory, that law is accepted by more people than theories.”

At the end of the study the participant answered the same question as:

“both of them are different kind of information . But both theory and law can change.”

In this way, teacher candidate D19 changed the poor view in to adequate at the end of the study.

This situation can be seen in the candidate teacher D19’s reflective writing. In teacher candidate D19’s reflective writing after the activity ‘what is in the box?’, s/he inferred: *“we guessed the thing in the box with shaking it, looking in it trough three holes ,listening the voice. We could not know if our guesses were right because science is not definite. You have to see what is inside the box.”*

At the beginning of the study D10, who had poor views about the tentative nature of science, but at the end of the study, by answering three questions of the survey consistently, changed his/her view into variable.

While answering the 10th question as:

“ Other sciences, like religion and philosophy, there are dogmatic opinions and they are based on subjectivity. I mean it is accepting the knowledge without discussing. But in science, everything is done with testing and observing. These can be done by even everyone, but the result is the same. There is a certainty.”

At the end of the application s/he answered the same question as below

“While studying in the scientific fields like physics and biology, we can do experiments and observations to support our hypothesis or guesses, in a field like philosophy it can’t ever be done. For instance, science can change, but religion can not.

To the 4th question s/he answered as:

“I don’t think theories can change, but I can not think of an example right now..” at the end of the application to the same question s/he answered:

“scientific theories can change. theories are true for that time. I mean when we do the research, if there is not a single contrasting idea, theory continues to be valid. For example the atom theory.”

To the 5th question participant answered as;

“Theory is accepted to be valid, but not for everyone. Theory is not universal. But law is universal. The information are accepted by everyone. Laws do not change.”

At the end of the application to the same question s/he answered as

“Law is the universal information accepted by everyone. Theory is not universal. For example, the law of gravity is accepted by everyone and it became universal and it is definite. But the big bang theory is not accepted by everyone and still remains a theory.”

In this way D10 teacher candidate, changes weak view into variable by mentioning that law can not change.

This situation can be seen in teacher candidate D10’S reflective writing which s/he wrote after the ‘tricky tracks’ activity. The teacher candidate D10 did not mention about the tentative nature of science.

“I do not know what these shapes are. Everybody thought about something else. For example I resembled these things to a fly, or footprint. But I am not sure.”

At the end of the study, there was a 25% increase in the number of the candidate teachers who has the adequate view about the tentative nature of science.

b) Empirical NOS

Table 4: Participants’ pre-post test about empirical NOS

GROUP		Participants’ Pre-test		Participants’ Post-test	
		f	%	f	%
Empirical NOS	A	33	92	36	100
	V	3	8	-	-
	P	-	-	-	-

At the beginning of the study, the majority of the pre-service teachers (92%) held also adequate views of the empirical NOS. After applying activity this rate increased to 100%. Thus, 8% increase was provided.

At the beginning of the study, while DE4, who had changeable views about the uncertainty of science nature, couldn’t give answer to second question, can give an answer to third question. As DE4 was giving answer;

‘Experiment is a thing that can be repeated and redone. Each thing we do can not be an experiment, in my opinion. In experiment there should be the ability to be done and to be repeated, and as a result of these there should be some things beneficial. We don’t always need the experiment.’

At the end of study s/he answered the same question in this way:

“Experiment is a case which can be tried over and over again. In my opinion, a requiring case has applicability in theoretically. To improve the scientific information, we always need experiments.”

To the 3rd question which was: 'Is there any necessity to experiment for improving scientific knowledge? Give an example.

While s/he was giving answer,

'Of course, it will be needed. Because when we write it on paper theoretically, we know the result but we do not have anything concrete. We can not gain definite things unless we concretize this.'

At the end of the study s/he answered the same question as:

'Yes, there is. Because we should transform a definite case from abstract to concrete.'

This is how teacher candidate DE4 converted his/her variable view to adequate at the end of study. This event can also be seen in the activity reports which DE4 teacher candidate wrote after activities of 'water generator' and 'perforated bottle'

In the 'water generator' report, teacher candidate wrote this in the section of observation data:

'This machine duplicates the water inside of it. Into machine, 150 ml water was filled with graduated beaker. After this, when we measure water quantity in the machine we observed that 650ml water is accumulated.'

At the same time, teacher candidates are told to design a model like this, and teacher candidate DE4 could design his own model and tried it out.

At the end of study, the experiment group which had the adequate view about the empirical nature of science, increased 8% but this was %5 in the control group.

c) Subjective NOS

Table 5: Participants' pre-post test about subjective NOS

GROUP		Participants' Pre-test		Participants' Post-test	
		f	%	f	%
Subjective NOS	A	-	-	3	8
	V	7	19	19	53
	P	29	81	14	39

At the beginning of the study, 81% of the participants did not recognize the role that background knowledge and training played in the scientists' development of scientific knowledge. Participants believed scientists were objective to give the best and fairest results in every condition. At the conclusion of the study, 8% of the participants held adequate views of the subjective NOS. Approximately half of the participants (53%) held variable views of the subjective NOS.

The change in the participants' view about the subjective nature of science can be seen in the response given in the surveys. At the beginning of the study, whereas Dk3 who had variable view about the subjective nature of science couldn't give an answer to question 1, s/he could answer 9th question. For example, while answering the 1st question which was: 'What is the meaning of science? What separates science from other fields?'

s/he answered as: 'It is an effort for understanding the nature with using quality and quantity observations which occur with people's curiosity and facilitating the life.' At the end of study, the answer to same question: "Science is composed of curiosity. Science is a current field for getting knowledge with searching subject which is intrigued by being found in the qualitative and quantitative observations and stating a product."

s/he answered the 9th question which was: 'Is the science effected social and cultural values or is it universal? Give an example.'

as :

“Yes, there are some points. I mean scientists’ view are subjective”

At the end of study, the participant’s answer to the same question was:

“Yes, it is effected. Because scientists are subjective during the study.” As a result, at the end of study, participant DK3 converted his variable view into adequate. This occasion can be seen in the participants’ reflective writing. In his reflective writing which he wrote after the activity ‘Is it young or old?’, participant DK3 inferred;

“First picture I saw is a young woman. But later I saw an old woman. Everybody in the class saw different things in the beginning. For example, some first saw young lady, some of them saw old lady. The first reason of this is different perceptions, views and expectations. Also scientists are subjective in their studies.”

At the beginning of the study, DK5 who had poor opinion about the subjective nature of science, at the end of study s/he had adequate view, gave answer in this way:

“It is a knowledge that inferred from objective experiments and observations. Other sciences, like religion and philosophy, there are dogmatic opinions and they are based on subjectivity. I mean it is accepting the knowledge without discussing. But in science, everything is done with testing and observing. These can be done by even everyone, but the result is the same. Objectivity, I mean that scientists should be objective in their works. They shouldn’t interfuse their own opinions to their studies”

At the end of study, s/he answered the same question as below :

“Science is the field which presents the solution with results of experiment and observation to the case being in the nature. While studying in the scientific fields like physics and biology, we can do experiments and observations to support our hypothesis or guesses, in a field like philosophy it can’t ever be done. At the same time, science has also subjectivity.”

To the 9th question the participant’s answer was:

“If we look at what I meant by telling that science is objective, then, science is universal.”

At the end of study; s/he gave an answer to the same question as below:

“In the stage of interpreting the data, scientists’ perspectives, prejudices, expectations effects their comments and these features differ from culture to culture. That is why social and cultural values has an impact on scientists’ ideas.”

In this way candidate DK5 changed his poor view into adequate at the end of study. This can be seen also in his reflective writing. In his reflective writing, which he wrote after the activity of ‘Let’s Find’, candidate DK5 inferred these results about the activity;

‘While I was reading passage, a medicine came to my mind in the first line. Then, reminiscent a computer. When I saw the vehicle, I thought it had an airbag. But if I didn’t have any experience, background knowledge about the vehicles, I wouldn’t know the vehicle. In conclusion, when the scientists were interpreting the data they collect, they use their expectations, background knowledge and imaginations. I mean science is subjective.’

At the beginning of the study, DK11 who had poor view about the subjective nature of science but had variable view at the end, gave answer to the 1st question as;

‘Science is the process of collecting information regularly. In philosophy, principle of the view is composed of a person’s own opinion. In my opinion, it is subjective rather than objective. Science is universal. Information is accepted by most of the people.’

At the end of study, s/he answered the same question as;

“Science is the process of reaching scientific knowledge. Science attends the whole case to reach knowledge. The important thing is having a conclusion from the whole case. Besides, sometimes unsuccessful results can be seen in science. I mean that the result can be different from the expectations. But it isn’t like that in religion and philosophy. Moreover science is universal but religion is not.”

To question 9, the answer she gave was:

“In the first stage it can be effected, later it becomes universal.”

At the end of study;

“Because human curiosity and human thoughts caused the beginning of science, science may reflect the values. For example: Galileo’s case.”

In this way, participant DK11 who had weak view at the end of study, changed this into variable view by giving response to 9th question that science is effected with social and cultural values.

This situation can be seen in the participant DK11’s reflective writing in reflective writing participant Dk11 wrote after ‘let’s find’ activity, inferred this about activity and didn’t mention about subjectivity directly.

‘First time I read, I thought it is a thing related with telephone. But there is no meaning in the whole passage. After I had learned that it is related with vehicle, I thought about an air bag. In my opinion; we can infer from this result that we should have background knowledge about any data to be meaningful.’

Although it seems like the change in the number of participants who has the adequate view is low, participants who have poor view is dramatically decreased.

At the end of study, less than half of the experiment group of candidates had poor view.

Most of the participants, who had poor views at the beginning, change their views into variable. While most of the participants who had variable views could give answer to 9th question related with subjective nature of science, they couldn’t answer 1st question. The reason of this is that teacher candidates actually comprehend that science is subjective but they chose wrong words to express their views.

Example: Participants didn’t properly know the meaning of subjective and objective words.

Thus, although activities directly related with reflective approach weren’t effective in improving the candidates’ view about subjective nature of science, they were effective in decreasing the number of participants who had poor view.

d) The Creative and Imaginative NOS

Table 6: Participants’ pre-post test about creative and imaginative NOS

GROUP		Participants’ Pre-test		Participants’ Post-test	
		f	%	f	%
The Creative and Imaginative NOS	A	8	22	30	83
	V	16	44	5	14
	P	12	33	1	3

%33 participants did not demonstrate adequate understandings of the role of imagination and creativity in generating scientific claims. Most participants did not appreciate the creative work in searching for patterns in data or developing models and theories. Students who believed that scientist use their creativity and imaginations, could not explained sufficiently in which part of their study and how they use those abilities. They ordinary put forward this idea though without proving and example of it.

In conclusion of the study, a total of 83% of the participants exited the course with more adequate understanding the role of creativity and imagination in science. They believed that science required creativity and imagination. Even though they all explained that scientists use their imaginations and creativity, they believed that scientists mostly use

those abilities while suggesting hypothesis than all the processes of in the scientific research.

Variation in teacher candidates' views about imaginative and creative nature of science can be seen also from the answers they gave during the interviews. At the beginning of study, DE11 who had a variable view about the imaginative and creative nature of science, couldn't give an answer to the 8th question, could answer to the 10th question. For instance the 8th question which he or she couldn't answer was: *"It is believed that dinosaurs existed 65 million years ago. There are two most accepted hypothesis formed by scientists in order to explain this existence. One of these hypotheses covers the idea of an enormous meteor that hit the earth and caused series of events which brought the extinction. On the other hand, the second hypothesis developed by other group of scientists shows that a major and intense volcanic eruption is responsible from the extinction. If all the scientists in both groups reach the same data and use the same data, how do these different results come up?"*

"I thought like that. Searching at that time, attrition in world, something was happened like an eruption or a disaster caused a sign in the world. One of the scientists told that it was volcanic eruption, the other told it was meteor. Both of them made effect. But the results are the same, effects are the same."

At the end of study, the participant's answer to the same question:

"This situation can be expressed like this. Two different people, events, data, time and at the but two different scientists. Both of them commented in a different way, perceived differently and had different imaginations."

The 10th question was: 'Do scientist use their imagine and creativity during their work? Give an example.'

The participant's answer was;

"In my opinion, they would use. Because, if there is no imagination and curiosity, there is no science. So, I believe they used their imagination and creativity."

At the end of study his/her answer to the same question was:

"Yes, scientists use their imaginations. First of all, information is planned, data is collected and at the end imagination and creativity are used for gathering and taking results form these. Without imagination and curiosity, science can not exist."

In this way, participant DE11 changed his variable view into adequate at the end of study.

This situation can be seen in the participant's reflective writing. In reflective writing s/he wrote after activity of 'Paper rolls', she inferred such results:

"In today's activity, we had that system made of laces got trough the rolls. When we stretched the laces above, crossed laces below were getting inside the roll, an then the other lace was going inside. Although our mechanism and other friends' mechanism were the same, they both worked in the same way. It was a result of the different perceptions, imaginations and opinions."

At the beginning of the study , DE1 who had poor view about the creative and imaginative nature of science but at the end had adequate view, gave answer to question 8 such as;

"They might have done the research with the same data but about different subjects. For instance, one might have thought about the ages of the fossils, and the other one might have thought about something else."

At the end of study the participant gave this answer to same question;

"In my opinion, it is the perspective that caused different results. Both of them have a different perspective while considering the events. They used their imaginations."

For the 10th question, his/her answer was:

"No, they don't use. But scientists think cleverer than us."

At the end of activity, the participant's answer was:

“Yes. In composing hypothesis, they used their imaginations and creativity. For example: in experiment of candle, everyone had different views. Some of them told that candle would die down, some told it would not. In this situation, it was a result of creativity and imagination.”

In this way, participant DE1 changed his poor view to adequate at the end of study. This case can be seen in the reflective writing s/he wrote

In reflective writing DE1 wrote after activity of ‘What is inside the box?’, s/he inferred this results:

‘I thought there is a pin inside the box. Because there was a metal sound. After scientist arrived this point they used their imaginations. In this activity, I answered according to my imagination and feelings. But there is no reality in science.’

At the end of study, while the number in the experiment group who had adequate view about the creativity and imaginative nature of science was increasing 61% in rate, this rate was 27% in the control group. In consequence, direct and reflective approaches were effective on improving the participants’ views about the imaginative and creative nature of science.

e) Observation versus Inference

Table 7: Participants’ pre-post test about observations versus inference

GROUP		Participants’ Pre-test		Participants’ Post-test	
		f	%	f	%
Observation versus Inference	A	2	6	23	64
	V	3	8	10	28
	P	31	86	3	8

At the beginning of the study, in response to the question “how certain are scientists about the structure of the atom and the evidence scientists used to derive this structure,” only 6% of the students reported adequate views on the difference between observation and inference. Most students (86%) believed some scientists have conducted some experiments and according to the experimental results, they believed that an atom looks like exactly as the model itself. At the conclusion of the study, 64% of the participant held adequate views of the observation versus inference. Thus, activity based on direct-reflective approaches were quite effective in improving views about nature of science based on inference. Though DE4 who had weak view about the nature of science based on inference, couldn’t give an answer to 7th question, he could answer the 6th question.

The answer s/he gave to the 6th question was:

“These are not laws but theories. I have no information about these. I learned about these from the books. In my opinion they are not sure. They just defended such way according to current findings. Maybe they are inspired from their imaginations. For example; when structure of cyclic revealed, scientist who found this, didn’t know it’s shape and he saw snake scale. They draw a conclusion by using their creativity and imagination.”

At the end of application s/he answered the same question as:

“In my opinion they profited from their experience and imaginations. Because they couldn’t see internal structure of atom. Thus they could profit from their imaginations to perceive an abstract event as a concrete. So they draw a conclusion like this.”

The 7th question which was : ‘Generally science books are defined the breed as having the same features and defined a mating group with each other for producing effective semen How can scientists be sure about features related with one breed?’

The participant answered as:

“If we go through the past times, when there were first breeds. While classifying them, in their first study of classification may be, they might have looked at only the external appearances.”

At the end of application his /her answer to the same question was:

“It could be according to its habitats, geographical locations, nutrition habits, physical appearance. They might have done this by observing and analyzing the breeds.”

In this way, participant DE4 turned the variable view into adequate by mentioning about observations in the 7th question at the end of the study. This case can be seen in the reflective writing s/he wrote. In reflective writing s/he wrote after the activity of ‘Old teacher’, participant DE4 inferred such result:

‘Scientists’ prejudice effects commenting data. Everybody observed the same thing but different comments were made. Because everybody had different inferences from each other.’

DK7 who had weak view but at the end adequate view about the nature of science based on inference at the beginning of study, gave answer:

“While describing what an atom resembles, primarily they analyzed the structure of atom. Because it can’t be without analyzing. Analyzing atom, they had already observed that atom composed of protons, neutrons and electrons.”

At the end of study, s/he answered the same question as:

“When scientists decided about the structure of atom, they collected data which based on the researches they had already did about the subject, after that they made comments about the things that may occur in the future. In order to see rights or wrongs in these comments, they decided to make experiments. And maybe they made comments and made inferences according to the results of those experiments.”

To the 7th question the participant gave this answer:

“If scientists named these as a breed, they named because of the similar structural living functions. Otherwise, each living has its own name, they would also evaluate them in such way.”

At the end of application h/she give answer to the same question as:

“Scientists primarily apply to the written sources for learning the structure of organisms, what they are composed of and scientists make analyses, for example in microscope, in the laboratory. After this, scientists classify organisms according to their similar structural features, I mean they analyze and observe.”

In this way, participant DK7’s weak view became adequate the end of study. It can be seen in the DK7’s reflective writing. In reflective writing s/he wrote after the activity of ‘Tricky signs’ participant DK7 inferred these results:

‘Actually, Figure 2 and Figure 3 are the parts of Figure 1. But when we look, we see different things although they are the pieces of the same puzzle. As a result of the observations, we see things different because of our imagination.’

At the beginning of the study DK5 who had weak view about the nature of science based on inference but had variable view at the end of study, while answering:

“When scientists told these, they made lot of research and they analyzed numerous time. They could analyze atoms using microscopes and tools in laboratory environment. And from now on, they would accept these because any contrast view to their sayings occurs.”

At the end of study to the same question, answered as:

“In their studies which they had so far, scientists couldn’t find any contrast thing about this situation and none of the scientists contradict. Scientists decided what an atom resembled by observing the movements and the particle places inside of an atom. Observing with microscopes.”

While answering as below to the 7th question:

“While defining a breed, scientists produce a common classification and make it general for every scientist, and they make their classifications for those with the most common features.”

At the end of study his/her answer was:

“When scientists classified the livings, they profited from the common features of livings. It was defined the most interesting and common features indentified in these breed. To decide what the breed is, most of the livings should be analyzed and observed.”

In this way, participant DK5, who had poor view at the end of study, became variable by answering to the 7th question with making such observation. It can be seen in the DK5’s reflective writing. In the reflective writing, participant DK5 wrote after the activity ‘Old Teacher; inferred such results and while s/he was mentioning about observation, s/he didn’t mention about the inference.

‘I observed an old teacher until Figure 6. After Figure 6, a young woman began to appear. But when we looked at the pictures at the same time, I recognized picture of a woman in Figure-4.’

f) Social and Cultural NOS

Table 8: Participants’ pre-post test about social and cultural NOS

GROUP		Participants’ Pre-test		Participants’ Post-test	
		f	%	f	%
Social and Cultural NOS	A	5	14	8	22
	V	4	11	9	25
	P	27	75	19	53

At the beginning of the study, the 14% of the preservice teachers were aware of the social and cultural influences on the interpretation of data. 75% of the participants held inadequate views of social and cultural NOS. They dismissed the possible influence of background knowledge and cultural background.

At the conclusion of the study, 22% of the participant held adequate views of the social and cultural NOS. There has been a minor change. But, rate of the poor views decreased 53%.

Consequently, activities based on direct and reflective approach, in improving participants’ view related with social and cultural nature of science, were effective even a little. DK3, who had weak view about social and cultural nature of science, couldn’t give answer to the 9th question.

Example: the answer s/he gave to the 9th question was:

“It is universal, just because it doesn’t suit to cultural values, scientific info which is found, can not be topic of unused. Knowledge is a cumulative process.”

At the end of application s/he answered the same question as:

“Effected by social and cultural values, example the environment, in which he lives in, can effect culture. At the same time, scientist may have wondered the hinges about environment he lives in. The point scientist more curious about is his living environment. Social experience and his culture or his living period may be effective about this. At past times, especially the time science was newly developed, human hesitated to reveal their scientific works. In this perspective, social environment effects the living period. For example, I can say this. We can talk about evolution theory. The time when evolution theory first appeared, now it is known as Darwin, but before Darwin, there were a lot of works .but the

reason why that works didn't reveal at that time was the religion pressure. Church was the authority then."

In this way, DK3 who had weak view at the end of study, converted to adequate. It can be seen in the DK3's reflective writing. In the reflective writing s/he wrote after activity 'A Scientist's picture', inferred such results:

'Scientist is a woman. Her hair is bun. There is laboratory glasses on her eyes. There is lab coat on her. She is wearing comfortable covered shoes. There are gloves on her hands and she did an experiment.'

DK5 who had poor view about social and cultural nature of science at the beginning but had adequate view at the end, answered the 9th question as:

"Science is objective, that is why it is universal. With science, we try to explain the cases in the nature. And about these cases in nature, we will have the same results when we go through the same stages. If it is treated objectively, right guesses are composed, I think the result would be universal."

The participants' answer to same question at the end of study;

"When scientists interpret data, because their features such perspectives, prejudices, expectations effect their comments, and because these features can show difference from community to community, scientists' views are effected by social and cultural values in commenting stage."

In this way, participant DK5 converted his weak opinion to adequate at the end. This case can be seen DK5's reflective writing .In his/her reflective s/he had wrote after activity of 'A scientist picture' inferred such results:

'Scientist may look for. Social environment effects scientist.'

DK8, who had weak view about social and cultural nature of science at the beginning but had changeable view at the end, couldn't give answer to question 9such:

"Science is universal in my opinion."

At the end of application, the participant's answer to same question:

"At the beginning of science, when scientist's impartial approach and curiosity occur, social and cultural values aren't being reflected. But community views effect these works over time. This situation reflects social and cultural values."

Thus, participant DK5 converted his/her weak view to variable at the end of the study.

g) Relationship Between Scientific Theories and Laws

Table 9: Participants' pre-post test about relationship between scientific theory and laws

GROUP		Participants' Pre-test		Participants' Post-test	
		f	%	f	%
Relationship Between Scientific Theories and Laws	A	-	-	8	22
	V	2	6	12	33
	P	24	94	16	44

94% of the participants reported inadequate notions about the theories and laws at the beginning of the study. Many believed in a notion that theories were simply meant to developing laws. Most students believed that with supportive experiments, theories would develop into laws. Thus, the kinds of knowledge explained by theories and laws were not different, just different in terms of the amount of "certainty" that supported each other. This led to the belief that laws were absolute and did not change because they had been "proven" and were the ultimate source of scientific knowledge.

At the final questionnaires and interviews 22% of the participants adopted the view that scientific theories and laws were different kinds of knowledge and that one did not develop in the other.

At the beginning of the study, while DK3, who had a variable view about the nature of science based on inference, could answer the 4th question, couldn't answer the 5th question. For example s/he answered the 4th question as: *“Actually, theory is seen too close to definite but the thing is, although laws are more definite than theories, there isn't 100%ration even in law. So, even laws have the probability of changing, theories have more probability compared to laws. The studies on atom theory can be shown as an example.”*

At the end of application;

“Theories can be changed. Now, even laws can be changed. In this condition, if even laws are changed, theories that has little definite, can be changed. According to relativity theory, something was added. Some points were changed.”

Question 5: Is there any difference between scientific theory and law? Give an example.

While giving answer to the 5th question as:

“Of course. Law is more generalized in definite comparing to theory. Passing much more time on theory, law occurs with supportive norms of that information. If anything is said in contrary, it can't occur. We can say that law is the upper step of theory.”

At the end of application s/he answered the same question ;

“Of course. Both of them are two kind of different information.”

In this way, participant DK3 who had variable view at the end of study, converted to adequate by answering that law and theory are two different kind of information.

At the beginning of the study, DK12, who had poor view about the difference between scientific theory but had adequate view at the end, gave answer to 4 such that:

“Theories can't change.”

At the end of study, the participant's answer to the same question was:

“Theories can change. Theories are valid until the contrary of them is demonstrated. For this reason, we are still learning theory. Example: evolution theory.”

While answering 5th question as below:

“Of course there is. Because law is the upper step of theory. It is the case that gains more validity.”

At the end of applications/he answered the same question as:

“Yes, there is. But both law and theory can be changed. Both of them are different information from each other.”

In this way, DK12 converted his poor view to adequate at the end of study.

DE18 who had poor view about difference between scientific law and theory but had variable view at the end, gave answer to question 4 such that:

“In my opinion, theories are not changed.”

At the end of study the participant answered the same question as:

“Theory can be change after enough time. We can learn new theories to get information about the current patterns, and recent studies. For example: Darwin's theory.”

To question 5 given answer was:

“There is a difference between law and theory. There are still discussions about theory so that, they are unproved tests. But laws are definitely proved. For example, on Darwin theory, there is still discussion. But Gauss law, nobody says Gauss law is wrong.”

At the end of application the participant answered the same question as:

“There is. Scientific laws validity is accepted without discussing and they are proved. But discussions still continue about the theories.”

RESULTS

Results of pre-service teachers' views of NOS

- The participants of this study held naive views of nearly all of the investigated aspects of the NOS at the beginning of the study, however they changed their views toward the “adequate” views after the intervention. The results of this study indicated that the explicit-reflective NOS teaching was “effective” at enhancing participant pre-service teachers' views. Participants made substantial gains in their understandings of the target aspects of NOS. It can be accepted basically as an achievement of explicit-reflective NOS teaching method.
- The explicit-reflective NOS teaching supported the pre-service teachers to understand tentative nature of science. Pre-service teachers who have adequate views were not a lot at the conclusion of the study. But, pre-service teachers with poor views were no.
- None of the participants held inadequate views of the empirical NOS at the conclusion of the study. The explicit-reflective NOS teaching was “effective” at enhancing pre-service teachers' views of empirical NOS.
- The explicit-reflective NOS teaching was little effective at enhancing pre-service teachers' views of subjective NOS. With poor views pre-service teachers' rate decreased.
- At the conclusion of the study, a majority of participants exited the lesson with more adequate understandings of the role of creativity and imagination in science. This is because of the teaching form of the NOS activities. The explicit-reflective NOS teaching was quite effective at enhancing pre-service teachers' views of creative NOS.
- At the conclusion of the study, most of participants expressed adequate views about the inferential nature of science. The explicit-reflective NOS teaching was quite effective at enhancing pre-service teachers' views of inferential NOS.
- Pre-service teachers' views of social and cultural NOS changed a little. However, explicit-reflective NOS teaching a little effective. At the conclusion of the study with poor views pre-service teachers' rate decreased.
- It was found that all participants explicated inadequate views about the relationship between theories and laws at the beginning of the study. Some of participants changed their views and adopted the view that scientific theories and laws are different kinds of knowledge and that one does not develop in the other. The explicit-reflective NOS teaching was effective at enhancing pre-service teachers' views of relationships between scientific theories and laws.

The pre-service teachers in the current study held naive views of the aspects of NOS at the beginning of the study. This result is quite consistent with research in the related literature (Akerson et al, 2000; Bianchini and Colburn, 2000; Akerson and Abd-El-Khalick, 2000; Akerson et al, 2006). However, several substantial and favorable changes in participants' conceptions of the target NOS aspects were evident at the conclusion of the study. These results substantiate our claim regarding the effectiveness of an explicit reflective approach in enhancing pre-service teachers' NOS views like the others (Abd-El-Khalick and Lederman, 1998). It is quite effective to teach NOS to pre-service teachers in an explicit-reflective way.

Finally, this study suggests some fruitful venues for future research. First, nature of science lesson should be given to pre-service teachers in university. Second, in-service courses about NOS are given to teachers.

REFERENCES

- Abd-El-Khalick, F., 2001. Embedding Nature of Science Instruction in Pre-service Elementary Science Courses: Abandoning Scientism, But.... *Journal of Science Teacher Education*, 12 (3): 215-233.
- Abd-El-Khalick, F. and Akerson, V.L., 2004. Learning as Conceptual Change: Factors Mediating the Development of Pre-service Elementary Teachers' Views of Nature of Science. Wiley Periodicals, Inc. *Sci. Ed.*, 88, 785 – 810.
- Abd-El-Khalick, F., and Lederman, N.G., 1998. Improving science teachers' conceptions of the nature of science: A critical review of the literature. Paper presented at the Annual meeting of the National Association for Research in Science Teaching, San Diego, CA.
- Abd-El-Khalick, F. and Lederman, N.G., 2000. Improving Science Teachers' Conceptions of Nature of Science: A Critical Review of the Literature, *International Journal of Science Education*, 22 (7): 665-701.
- Abd-El-Khalick, F., Bell, R.L., and Lederman, N.G., 1998. The nature of science and instructional practice: Making the unnatural natural. *Science Education*, 82, 417-436.
- Abd-El-Khalick, F, Waters, M. & Le, A. 2008. Representations of nature of science in high school chemistry textbooks over the past four decades. *Journal of Research in Science Teaching*, 45(7), 835-855.
- Akerson, V.L. and Abd-El-Khalick, F.S., 2000. Improving Pre-Service Elementary Teachers' Conceptions of the Nature of Science Using a Conceptual Change Teaching Approach, International Conference of the Association for the Education of Teachers in Science, Akron, Ohio.
- Akerson, V.L. and Hanuscin D., 2007. Teaching The Nature Of Science Through Inquiry: The Results Of A Three-Year Professional Development Program. *Journal of Research in Science Teaching*, 44 (5): 653-680.
- Akerson, V.L., Abd-El-Khalick, F.S., and Lederman, N.G., 2000. Influence of a reflective activity based approach on elementary teachers' conceptions of the nature of science. *Journal of Research in Science Teaching*, 37, 295–317.
- Akerson, V.L., Morrison, J.A., and McDuffie, A.R., 2006. One Course Is Not Enough: Pre-service Elementary Teachers' Retention Of Improved Views Of Nature of Science. *Journal of Research In Science Teaching*, 43 (2): 194-213.
- Bell, R. L., Lederman, N.G. and Abd-El-Khalick, F. 2000. Developing And Acting upon One's Conception of the Nature of Science: A Follow-Up Study, *Journal of Research in Science Teaching.*, 37, 563-581.
- Bell, R.L., Matkins, J.J. and Gansneder, M.B., 2011. Impacts of Contextual and Explicit Instruction on Preservice Elementary Teachers' Understandings of The Nature of Science. *Journal of Research in Science Teaching*, 48 (4): 414-436.
- Bianchini, J.A. and Colburn, A., 2000. Teaching the nature of science through inquiry to prospective elementary teachers: A tale of two researchers. *Journal of Research in Science Australian Journal of Teacher Education Teaching*, 37, 177–209.
- Blanco, R. & Niaz, M. 1997. Epistemological beliefs of students and teachers about the nature of science: from 'baconian inductive ascent' to the 'irrelevance' of scientific laws. *Instructional Science*. 25(3), 203-231.
- Briscoe, C., 1991. The Dynamic Interactions among Beliefs, Role Metaphors and Teaching Practices. A Case Study of Teacher Change. *Science Education*, 75 (2): 185–99.
- Carey, S., Evans, R., Honda, M., Jay, E. and Unger, C., 1989. An Experiment Is When You Try It And See If It Works: A Study Of Grade 7 Students' Understanding Of

- The Construction Of Scientific Knowledge. *International Journal of Science Education*, 11, 514-529.
- Cartier, J. 2000. Using a modeling approach to explore scientific epistemology with high school biology students. Research Report, National Center for Improving Student Learning and Achievement in Mathematics and Science, University of Wisconsin-Madison, Madison, WI.
- Driver, R., Leach, J., Millar, R. and Scott, P., 1996. *Young People's Images of Science*. Buckingham, UK: Open University Press.
- Fishwild, J.E., 2005. *Modeling Instruction And The Nature Of Science*. Unpublished Master Thesis, University of Wisconsin-Whitewater.
- Hogan, K., 2000. Exploring a Process View of Students' Knowledge about the Nature of Science, *Science Education*, 84, 51–70.
- Irez, S. 2006. Are we prepared?: An assessment of preservice science teacher educators' beliefs about nature of science. *Science Teacher Education*, 90(6), 1113-1143.
- Irwin, A. R., 2000. Historical Case Studies: Teaching the Nature of Science in Context, *Science Education*, 84, 5-26.
- Khishfe, R., 2008. The Development of Seventh Graders' Views of Nature of Science. *Journal of Research In Science Teaching*, 45 (4): 470–496.
- Khishfe, R. and Abd-El-Khalick, F., 2002. 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.
- Klopfer, L. and Cooley, W., 1963. The History of Science Cases for High Schools in the Development of Student Understanding of Science And Scientists, *Journal of Research in Science Teaching*, 1, 33-47.
- Klopfer, L.E. and Watson, F. G., 1957. Historical Materials and High School Science Teaching, *The Science Teacher*, 24, 264-293.
- Küçük, M., 2006. *A Study Toward Teaching the Nature of Science For Seventh Grade Primary Students*. Unpublished PhD Dissertation, University of Karadeniz Teknik.
- Lederman, N.G., 1992. Students' and Teachers' Conceptions of the Nature of Science: A Review of the Research, *Journal of Research in Science Teaching*, 29 (4): 331-359.
- Lederman, N. G. 1998. The state of science education: Subject matter without context. *Electronic Journal of Science Education*, 3 (2). [http : // ejse. southwestern. Edu / original %20 site / manuscripts/v3n2/articles/guest%20editorial/lederman.html](http://ejse.southwestern.edu/original/site/manuscripts/v3n2/articles/guest%20editorial/lederman.html). adresinden 1Nisan, 2008 tarihinde edinilmiştir.
- Lederman, N.G., 1999. Teachers' Understanding of the Nature of Science And Classroom Practice: Factors That Facilitate or Impede The Relationship, *Journal of Research in Science Teaching*, 36 (8): 916–929.
- Lederman, N. G., and Abd-El-Khalick, F. 1998. Avoiding de-natured science: Activities that promote understandings of the nature of science. In W. McComas (Ed.), *The nature of science in science education: Rationales and strategies*. Dordrecht, The Netherlands: Kluwer
- Lederman, N. G., Farber, P. L., Abd-El-Khalick, F., and Bell, R. L 1998. The myth of the scientific method and slippery debates in the classroom: A response to McCreary. *The Oregon Science Teacher*, 39 (4): 24-27.
- Lederman, N.G., Abd-El-Khalick, F., Bell, R.L. and Schwartz, R.S., 2002. Views of Nature of Science Questionnaire (VNOS): Toward Valid And Meaningful Assessment of Learners' Conceptions of Nature of Science, *Journal of Research in Science Teaching*, 39, 497-521.
- Matkins, J.J., Bell, R.L., Irving, K., and McNall, R. 2002. Impacts of contextual and explicit instruction on pre-service elementary teachers' understandings of the nature

- of science. Proceedings of the 2002 Annual International Conference of the Association for the Education of Teachers in Science. Pensacola, FL: Association for the Education of Teachers in Science.
- McComas, W. F. 1998. The principle elements of the nature of science: Dispelling the myths. In W.F. McComas (Eds.). *The nature of science in science education: Rationales and strategies* (pp. 53–70). Dordrecht, the Netherlands: Kluwer Academic Publishers.
- McComas, M.R. 2003. A textbook case of the nature of science: Laws and theories in the science of biology. *International Journal of Science and Mathematics Education*, 1(2), 141-155.
- McComas, W. R., Clough, M. P., & Almazroa, H. 2002. The role and character of the nature of science in science education. In W. McComas (Ed.), *The nature of science in science education: Rationales and strategies* (pp. 3-41). New York: Kluwer Academic.
- McDonald, C.V., 2008. Exploring The Influence of a Science Content Course Incorporating Explicit Nature of Science and Argumentation Instruction on Pre-service Primary Teachers' Views of Nature of Science. Unpublished PhD Dissertation, University of Queensland.
- McDonald, C.V., 2010. The Influence of Explicit Nature of Science and Argumentation Instruction on Preservice Primary Teachers' Views of Nature of Science. School of Education and Professional Studies, Griffith University.
- Meichtry, Y.J., 1992. Influencing Student Understanding of the Nature of Science: Data From A Case of Curriculum Development, *Journal of Research in Science Teaching*, 29 (4): 389-407.
- Moss, D.M., Abrams, E.D. and Kull, J.R., 1998. Describing Students Conceptions of the Nature of Science Over An Entire School Years, Annual Meeting of the National Association for Research in Science Teaching. San Diego, CA.
- Reif, F. and Larkin, J.H., 1991. Cognition in Scientific And Everyday Domains: Comparison And Learning Implications, *Journal of Research in Science Teaching*, 28, 733-760.
- Rutherford, F. J., Holton, G. and Watson, F. G., 1970 *The Project Physics Course*. New York: Holt, Rinehart & Winston.
- Ryan, A. G.& Aikenhead, G.S. 1992. Students' preconceptions about the epistemology of science. *Science Education*, 76, (6), 559-580.
- Schwartz, R. S., Lederman, N.G., and Crawford, B.A., 2004. *Developing Views Of Science In An Authentic Context: An Explicit Approach To Bridging The Gap Between Nature Of Science And Scientific Inquiry*. Science Education.
- Shamos, M. 1995. *The myth of scientific literacy*. New Brunswick, NJ: Rutgers University Press.
- Solomon, J., Duveen, J., Scot, L. and Mccarthy, S., 1992. Teaching about the Nature of Science through History: Action Research in the Classroom, *Journal of Research in Science Teaching*, 29, 409-421.
- Strauss, A. and Corbin, J., 1990. *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. Ondon, Sage Publications.
- Tamir, P., 1972. Understanding The Process Of Science By Students Exposed To Different Science Curricula In Israel. *Journal of Research in Science Teaching* 9 (3): 239-245.
- Trent, J., 1965. The Attainment of the Concept "Understanding Science" Using Contrasting Physics Courses, *Journal of Research in Science Teaching*, 3, 224-229.
- Welch, W.W. and Walberg, H.J., 1972. A National Experiment in Curriculum Evaluation, *American Educational Research Journal*, 9, 373-383.