EXPLORING THE DEVELOPMENT OF PRE-SERVICE SCIENCE TEACHERS' VIEWS ON NATURE OF SCIENCE IN INQUIRY-BASED LABORATORY INSTRUCTION

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ABSTRACT

EXPLORING THE DEVELOPMENT OF PRE-SERVICE SCIENCE TEACHERS' VIEWS ON NATURE OF SCIENCE IN INQUIRY-BASED LABORATORY INSTRUCTION

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The purposes of this study were to explore understanding of preservice science teachers' (PSTs) nature of science (NOS) views during the explicit-reflective and inquiry-based laboratory instruction and investigate PSTs' perspectives and experiences related to learning NOS aspects in the science laboratory course. This study was carried out during the Laboratory Application in Science II course. A total of 45 PSTs participated to the study. The design of the study was qualitative and exploratory in nature. In the initial phase of the study, the researcher collected qualitative data with open-ended questionnaire to explore PSTs' NOS views. Then, during the semester, reflection papers were collected to understand PSTs' experiences with the intervention and to detect development about each NOS aspect. At the end of the semester, qualitative questionnaire and semi-structured interviews were conducted to determine the impact of the explicit-reflective and inquiry-based laboratory instruction. The results showed that all of the PSTs were able to make appropriate connections among the laboratory activities and the targeted NOS aspects at the end of the instruction. In addition, many PSTs developed their understanding levels of each aspect of nature of science. Moreover, findings revealed that some of the PSTs made connections among NOS aspects. Three main factors; discussions and presentations, using inquiry skills, and doing inquiry-based laboratory activities were determined as provide to PSTs to develop their NOS understanding. Furthermore, at the end PSTs developed their perspectives about teaching NOS.

Keywords: Nature of science, Explicit-reflective and inquiry based instruction, Science laboratory, Preservice science teachers.

ÖZ

FEN BİLGİSİ ÖĞRETMEN ADAYLARININ BİLİMİN DOĞASINA YÖNELİK GÖRÜŞLERİNİN GELİŞİMİNİN SORGULAYICI ÖĞRETİME DAYALI LABORATUAR DERSİNDE İNCELENMESİ

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Bu çalışmanın amacı ilköğretim fen bilgisi öğretmen adaylarının bilimin doğasına yönelik görüşlerinin doğrudan-yansıtıcı ve sorgulamaya dayalı laboratuar öğretimiyle gelişiminin incelenmesi ve öğretmen adaylarının bilimin doğasıyla ilgili olarak algıları ve deneyimlerinin neler olduğunun araştırılmasıdır. Bu çalışma Fen Bilgisinde Laboratuar Uygulamaları II dersinde yapılmıştır. Toplam 45 fen bilgisi öğretmen adayı bu çalışmaya katılmıştır. Bu çalışmada öğretmen adaylarının bilimin doğasına yönelik anlayışlarının gelişimini tespit etmek için nitel araştırma yöntemi kullanılmıştır. Çalışmanın başlangıcında öğretmen adaylarının bilimin doğasına yönelik görüşlerini belirlemek için açık uçlu sorular içeren ölçek kullanılarak veri toplanmıştır. Çalışma boyunca her hafta öğretmen adaylarının deneyimlerinin anlaşılması ve bilimin doğası hakkındaki gelişimlerinin belirlenmesi için yazılı dokümanlar toplandı. Dönemin sonunda doğrudan-yansıtıcı ve araştırmaya dayalı laboratuar öğretiminin etkisini belirlemek için öğretmen adaylarıyla mülakat yapıldı ve açık uçlu sorulardan oluşan ölçek tekrar uygulandı. Bu çalışmanın sonucunda bütün öğretmen adaylarının yapılan laboratuar etkinlikleriyle bilimsel bilginin karakteristik özellikleri arasında ilişki kurdukları ortaya çıkmıştır. Ayrıca öğretmen adaylarının çoğunun bilimin doğasına yönelik anlayışlarının geliştiği görülmüştür. Buna ek olarak bazı öğretmen adaylarının bilimsel bilginin özellikleri arasında ilişki kurdukları belirlenmiştir. Çalışma boyunca üç önemli faktör; tartışmalar ve sunumlar, araştırma becerilerinin kullanılması ve araştırmaya dayalı laboratuar etkinliklerinin yapılması öğretmen adaylarının bilimin doğasına yönelik anlayışlarını geliştiren faktörler olarak belirlenmiştir. Son olarak öğretmen adaylarının bilimin doğasının öğretimine yönelik algılarının pozitif yönde değiştiği tespit edilmiştir. Elde edilen bulgular sonucunda doğrudan-yansıtıcı yaklaşımın araştırmaya dayalı laboratuar öğretimiyle birbirini tamamladığı ve etkili bir yöntem olduğu ortaya konulmuştur.

Anahtar kelimeler: Bilimin doğası, Doğrudan-yansıtıcı ve araştırmaya dayalı laboratuar öğretimi, Fen laboratuarı, Fen bilgisi öğretmen adayları

To my parents Gülsüm and Mehmet

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my cute son Mehmet Eren

and my love Şebnem

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ABBREVIATIONS

AAAS: American Association for the Advancement of Science

CCM: Conceptual Change Model

MoNE: Ministry of National Education in Turkey

NOS: Nature of Science

NRC: National Research Council

NSES: National Science Education Standards

NSKS: Nature of Scientific Knowledge Scale

NSTA: National Science Teachers Association

SI: Scientific Inquiry

SPS: Science Process Skills

STS: Science, Technology, and Society

PST: Preservice Science Teacher

VNOS-B: Views of Nature of Science Questionnaire Version B

VOSTS: Views of Science, Technology, and Society

CHAPTER 1

INTRODUCTION

Understanding the nature of science (NOS) is an essential component of scientific literacy. Therefore, helping students to develop an adequate understanding of NOS is one of the most commonly declared objectives for science education (Abd-El-Khalick & Lederman, 2000; American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996). It is commonly accepted that a scientifically literate student should develop a functional understanding of NOS (Abd-El-Khalick, Bell, & Lederman, 1998; National Science Teachers Association [NSTA], 1982).

Scientific literacy is a general and broad concept. It is related to helping individuals adjust to life in modern society. However, because society is continuously changing, scientific literacy has had a wide variety of meanings since when it was first introduced in the late 1950s (DeBoer, 2000). Although there is a consensus among educators about the importance of scientific literacy, there is no one clear definition of that is generally accepted and used in science education (Bybee, 1997). In the past, NSTA identified scientific literacy as the main purpose of science education and it suggested this purpose for all students, not just for students pursuing careers in science and engineering. NSTA defined a scientifically literate person as one who "uses science concepts, process skills, and values in making everyday decisions as he interacts with other people and with his environment" and also who "understands the interrelationships between science, technology and other facets of society, including social and economic development" (NSTA, 1971, p. 47 - 48).

Scientific literacy was aimed at all students, therefore researchers focused on this topic at all levels. Because of uncertainty of definition, science educators used scientific literacy in various ways (Norris & Phillips, 2002). However, understanding of NOS and scientific inquiry (SI) are accepted important components of scientific literacy. Major education organizations in science education emphasized the importance of students' understanding of NOS and SI (AAAS, 1990, 1993; Ministry of National Education in Turkey [MoNE], 2004; NRC, 1996; NSTA, 1971). In this study, preservice science teachers' (PSTs) NOS understanding in inquiry learning environment was explored. PSTs will be science teachers at elementary schools after their graduation. Their understanding levels of NOS will affect their teaching in science classes.

1.1 Nature of Science (NOS)

Although science organizations (AAAS, 1990, 1993; MoNE, 2004; NRC, 1996; NSTA, 1971) and science educators aimed to develop conceptions of NOS, there is no one common accepted definition of NOS, and it has been defined in numerous ways (Alters, 1997). Abd-el-Khalick, Bell, and Lederman (1998) defined

NOS as “typically, the nature of science has been used to refer to epistemology of science, science a way of knowing, or the values and beliefs inherent to the development of scientific knowledge” (p.418). According to another study, NOS “refers to the values and underlying assumptions that are intrinsic to scientific knowledge, including the influences and limitations that result from science as a human endeavor” (Schwartz, Lederman & Crawford, 2004, p.611). Although both definitions are similar, the latter is more suitable for the present study.

Some aspects of NOS especially related to K-16 education are unproblematic and there is a consensus about definitions of the NOS aspects (Abd-El-Khalick, 2001; Abd-El-Khalick & Akerson, 2004; Schwartz, Lederman & Crawford, 2004; Smith, Lederman, Bell, McComas, & Clough, 1997). Schwartz, Lederman, and Crawford’ (2004, p.613) definitions of NOS aspects were used in this study. Table 1.1 presents these definitions.

Table 1.1. NOS Aspects and their Definitions

NOS Aspects	Definitions
Tentativeness	Scientific knowledge is subject to change with new observations and with the reinterpretations of existing observations. All other aspects of NOS provide rationale for the tentativeness of scientific knowledge.
Empirical basis	Scientific knowledge is based on and/or derived from observations of the natural world.
Subjectivity	Science is influenced and driven by the presently accepted scientific theories and laws. The development of questions, investigations, and interpretations of data are filtered through the lens of current theory. This is an unavoidable subjectivity that allows science to progress and remain consistent, yet also

	contributes to change in science when previous evidence is examined from the perspective of new knowledge. Personal subjectivity is also unavoidable. Personal values, agendas, and prior experiences dictate what and how scientists conduct their work.
Creativity	Scientific knowledge is created from human imaginations and logical reasoning. This creation is based on observations and inferences of the natural world.
Socio-cultural embeddedness	Science is a human endeavor and is influenced by the society and culture in which it is practiced. The values of the culture determine what and how science is conducted, interpreted, accepted, and utilized.
Observation and inference	Science is based on both observation and inference. Observations are gathered through human senses or extensions of those senses. Inferences are interpretations of those observations. Perspectives of current science and the scientist guide both observations and inferences. Multiple perspectives contribute to valid multiple interpretations of observations.
Laws and theories	Theories and laws are different kinds of scientific knowledge. Laws describe relationships, observed or perceived, of phenomena in nature. Theories are inferred explanations for natural phenomena and mechanisms for relationships among natural phenomena. Hypotheses in science may lead to either theories or laws with the accumulation of substantial supporting evidence and acceptance in the scientific community. Theories and laws do not progress into one and another, in the hierarchical sense, for they are distinctly and functionally different types of knowledge.

Source; Schwartz, Lederman, and Crawford, 2004, p.613

Abd-El-Khalick and Lederman (2000) and Lederman (1992) reviewed past studies about understanding of NOS in order to clarify what has been learned from earlier investigations. According to these reviews, most of the research during the 1960s and the 1970s revealed that many science teachers had inadequate NOS conceptions. Similar results were found during the 1980s and the early 1990s studies. After this undesirable result, some researchers focused on ways to improve teachers' NOS conceptions. Studies showed that promoting teachers' NOS conceptions improved students' understanding of NOS (Lederman, 2007). The current study aimed to improve PSTs' understanding of NOS aspects.

1.2 Scientific Inquiry (SI)

After the 1990s, major reforms in science education included SI as an important part of scientific literacy (NRC, 1996). Schwartz, Lederman, and Crawford (2004) emphasized that SI refers to characteristics of the scientific enterprise and the methods that guide the development of scientific knowledge. In this study, inquiry-based laboratory activities were used to improve PSTs' NOS views.

As a teaching approach, National Science Education Standards (NSES) mainly focus on inquiry. Inquiry is defined as a multifaceted activity that involves observations, inferences, formulating hypotheses, designing investigations, defining variables, collecting data, and interpreting and communicating results (NRC, 2000). From this definition, it is clear that the inquiry teaching method emphasizes the use of the science process skills (SPS), such as observation, collect of data, experimentation etc. in gaining scientific knowledge.

According to NRC Standards (2000), SPS are integrated into the broader abilities of scientific inquiry. Therefore, the Standards include the “process of science” and require that students combine SPS and scientific knowledge, this allows students to understand scientific concepts and understand of NOS aspects. During the study, the participants completed inquiry-based laboratory activities. These activities required using SPS.

1.3 Science Laboratory

More than several decades science laboratory courses have been an important part of science education (Garnett & Hacking, 1995). Laboratory courses play a crucial role to enhance students’ understanding of science concepts and they provide suitable environments to develop scientific process skills and problem solving abilities (Hofstein & Mamlok-Naaman, 2007; Lunetta, 1998). Tobin (1990) emphasized that “Laboratory activities appeal as a way to learn with understanding and, at the same time, engage in a process of constructing knowledge by doing science” (p. 405). Moreover, many educators agreed that meaningful in learning for science cannot be achieved without practical experiences and science laboratories are best for required practical experiences (Hofstein & Lunetta, 1982, 2004; Hofstein & Mamlok-Naaman, 2007; Tobin, 1990).

Although the importance of laboratory was accepted during the past century, studies about science laboratories could not represent its values (Domin, 2007; NRC, 2005). Roth (1994) wrote, “Although laboratories have long been recognized for their potential to facilitate the learning of science concepts and skills, this potential has yet to be realized” (p. 197). The present study used science laboratory, because it provided a convenient environment to conduct the inquiry-based laboratory activities.

Recently, the National Research Council (NRC, 2005) prepared a report for National Science Foundation, America’s Lab Report: Investigations in High School Science (ALR). The report emphasized the importance of science laboratory for science teaching, “(science education) would not be about science if it did not include opportunities for students to learn about both the process and the content of science” (NRC, 2005, p. 3). The report focused on some goals research tried to handle during laboratory base investigations, mastery of subject matter, developing scientific reasoning, understanding the complexity and ambiguity of empirical work, cultivating interest in science and learning science, developing teamwork abilities, understanding of NOS, and developing process skills (NRC, 2005). In this study, developing understanding of NOS aspects was concerned primary for PSTs.

There are four main styles for laboratory instruction, these are (1) traditional expository, (2) discovery (guided-inquiry), (3) problem based, and (4) inquiry (open-inquiry) (Domin, 1999). These styles are different in terms of their outcomes, approaches, and procedures. Moreover, new standards for science teaching (NRC, 2000) proposed applying inquiry-based laboratories to grow scientifically literate people, because this type of courses give a chance students to ask questions, develop hypotheses, conduct experiments, share and discuss results (Hofstein & Mamlok-Naaman, 2007). In this study, inquiry-based laboratory instruction was applied.

Many of the studies to develop NOS views were applied in the context of science method courses (Abd-El-Khalick & Akerson, 2004; Akerson, Abd-El-

Khalick & Lederman, 2000). Akerson et al. (2000) stressed that method courses might not be favorable contexts to develop science teachers' NOS understanding. Moreover, they suggested science content course as "An explicit-reflective approach to NOS instruction embedded in the context of learning science content would not only facilitate developing science teachers' NOS views, but might go a long way in helping teachers translate their understandings into actual classroom practice" (p. 297). This study was conducted in a science laboratory course, which included science contexts, such as photosynthesis and evolution.

1.4 Theoretical Framework

There are several epistemological approaches to understand the nature of scientific knowledge. Some of them are very important and they influenced the development of curricula from kindergarten to university. These are positivism, rationalism, realism, and constructivism (Matson & Parsons, 1998). The current study was conducted within the constructivist approach. Constructivism has an important role in developing scientific literacy in real experience and it is important to understand natural events throughout SI (Kaufman, 2004).

The main idea in constructivism is that knowledge is not transmitted directly from one knower to another, but that learners construct their own knowledge (Driver, Asoko, Leach, Mortimer, & Scott, 1994). According to constructivism, knowledge and the individual cannot be separated from each other. Thus, there are three different constructivism views from different positions such as radical, Piagetian, and socio-cultural. These different positions provide a variety of answers to the question:

What factors are the most important in constructing knowledge? (Matson & Parsons, 2006) In this part, Piagetian and socio-cultural approaches are discussed.

Piagetian (personal) constructivism emphasizes an individual's interactions with his/her physical environment in constructing knowledge. Piaget developed intellectual development theory in order to explain how people learn and how the human intellectual develops. Piaget (1966) developed his theory about human intellectual development on the basis of these observations and interviews. According to this theory, cognitive structures of learners change dependent upon individual-environmental interaction. The main idea here is that learners' experiences affect their cognitive structures. According to Piaget, meaning depends on the individual's current knowledge schemes. A learner can learn when those schemes change through the resolution of disequilibration. Sometimes individual needs internal mental activity and uses a previous knowledge to modify the scheme. Thus, individual learning is related to a process of conceptual change (Driver, Asoko, Leach, Mortimer, & Scott, 1994).

Many studies in science education literature showed that students do not come into science classes without any pre-instructional knowledge about the subjects to be taught. Students bring together their conceptions and ideas that are not in accordance with the science views or generally they contrast to them (Duit & Traegust, 2003). The conceptual change model (CCM) was developed by Posner, Strike, Hewson, and Gertzog (1982), and used as a way of thinking about the learning of disciplinary content such as physics and biology. In this model, learning includes changing a learner's conceptions in addition to an interaction between new and existing conceptions (Hewson, 1992). There are four conditions identified in the conceptual change model. First, learners confronted with a new condition use their existing knowledge (their learning ecology) to determine whether it is different or not, if it is different dissatisfaction condition occurred. Second, whether the new condition is intelligible (knowing what it means) or not. Third, whether the new condition is plausible (believing it to be true) or not. And fourth, whether the new condition is fruitful (finding it useful) or not (Hewson, Beeth, &Thorley, 1998).

Socio-cultural constructivism (Ausubel, 1968; Vygotsky, 1962) stressed the most important factors in knowledge construction as cultural environment, because while learners construct their scientific knowledge they are influenced by social experiences (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Matson & Parsons, 2006). In this approach, scientific knowledge is constructed when individuals engage socially in talk and activity about shared problems or tasks. Learning is accepted as a process in which learners are introduced by well-informed members (Driver, Asoko, Leach, Mortimer, & Scott, 1994). Therefore, it can be said that learning science in the classroom environment involves both personal and social processes.

Constructivism is not a teaching method or strategy, but it is a learning approach. There are some methods to apply this approach, for example; inquiry-based teaching, laboratory teaching, and conceptual change teaching. As it mentioned before, in this study the inquiry-based laboratory instruction was applied.

During the inquiry-based laboratory instruction, the explicit-reflective approach was applied to improve PSTs' NOS views. According to NOS literature there are two general approaches to improve NOS views, these are explicit-reflective and implicit (Abd-El-Khalick & Lederman, 2000; Lederman, 2007). Khishfe and Abd-El-Khalick (2002) defined explicit-reflective as: “An explicit and reflective approach emphasizes student awareness of certain NOS aspects in relation to the science-based activities in which they are engaged, and student reflection on these activities from within a framework comprising these NOS aspects" (Khishfe & Abd-El-Khalick, 2002, p.555).

Abd-El-Khalick and Lederman (2000) stated; "Explicitness and reflectiveness should be given prominence in any future attempts aimed at improving teachers' concepts of NOS" (p. 1). Although the researchers suggested using the explicit-reflective approach, they emphasized that "involving learners in science-based inquiry activities can be more of an explicit approach if the learners were provided with opportunities to reflect on their experiences from within a conceptual framework that explicates some aspects of NOS" (p. 689). Moreover, Lederman (2007) stressed the importance of using SI to improve NOS aspects saying; "NOS is best taught within a context of scientific inquiry or activities that are reasonable facsimiles of inquiry. That is, inquiry experiences provide students with foundational experiences upon which to reflect about aspects of NOS" (p. 835). Inquiry-based laboratory activities are used in the current study, and PSTs had chances to reflect their understandings about NOS. In this study, when using explicit-reflective approach how PSTs' views about NOS developed and changed were investigated. Therefore, findings of this research could provide information to teacher educators on how to better educate their preservice teachers about the use of inquiry skills and about understanding NOS in their courses.

1.5 Significance of the Study and Research Questions

Despite much research over the past several decades, there is evidence that prospective and practicing teachers have some misconceptions about NOS (Abd-El-Khalick & BouJaoude, 1997; Abd-El-Khalick & Lederman, 2000; King, 1991; Lederman, 1992; Lederman, 2007; Yager & Wick, 1966). This is a problem because if teachers have misconceptions about NOS, they might pass those misconceptions onto their students. Research showed that a teacher's all actions affect students' learning in class, and that learners' gains were not independent of teachers' NOS understandings (Lederman, 1992). In order to teach NOS, science teachers should have adequate experiences and understandings of NOS during their education.

After some important reform documents (AAAS, 1990; NRC, 1996; NSES, 2000), many countries (Canada, USA, Australia, South Africa, United Kingdom, New Zealand, Turkey) inserted NOS in their science curricula (Lederman, 2007). For example, the Turkish elementary science curriculum was redesigned to include goals and objectives related to NOS (Ministry of National Education in Turkey [MoNE], 2004). The vision of the new program is to raise science literate students throughout their schooling regardless of whether or not they will pursue the goal of involving in science or science teaching (MoNE, 2004). Moreover, in the new curriculum the science courses include technology, society, and environment relationships. Because the new dimensions were included in science curriculum, the course name was changed to science and technology. The science and technology course aims to increase students' science literacy by enabling them to master seven issues. These issues are: (1) the nature of science (NOS) and technology, (2) key science concepts,

(3) Science Process Skills (SPS), (4) the relation of science, technology, society, and environment, (5) scientific and technical psychomotor skills, (6) the values constructing the essence of science, and (7) attitude and values toward science (MoNE, 2004). In accordance with these dimensions, the new Turkish elementary science and technology curriculum aims to enhance students' understanding of NOS and develop their SPS.

Teachers are accepted as a significant factor in improving students' understandings of NOS aspects (Lederman, 2007). If science teachers do not understand NOS and why it is important to teach it, they may not apply an important part of the Turkish redesigned science curriculum. This will affect the opportunities that they provide their students to understand NOS. Ultimately, the goals and objectives of gaining an understanding of NOS outlined in the new science curriculum cannot be achieved without teachers' informed efforts. If teachers do not apply the curriculum correctly, the curriculum loses its value related to NOS understandings. The sample of this study was PSTs, who will teach new science curriculum after graduated the university.

New science programs all around the world emphasized the crucial role of teachers in the learning environment. The National Science Education Standards [NSES] (NRC, 1996) set standards for teacher knowledge of science and science teaching. The NSES state: "All teachers of science must have a strong, broad base of scientific knowledge extensive enough for them to understand the nature of scientific inquiry, its central role in science, and how to use the skills and processes of scientific inquiry" (p.59). Elementary science teachers have an important role in encouraging students to learn science effectively by using their inquiry skills and by understanding NOS. The role of teachers requires knowledge and enough proficiency in teaching NOS and process skills. Therefore, it is necessary to investigate this matter during teacher education programs to better help preservice science teachers.

Research has shown several promising ways to improve preservice teachers' understanding of NOS; however, more research is needed to address this problem. For example, in the most recent Handbook of Research on Science Education (Abell & Lederman, 2007), several guidelines for future directions of research related to NOS are outlined. In particular, questions to be answered include the following: (1) Is explicit instruction in the context of a laboratory investigation effective? (2) How do teachers' conceptions of the nature of science develop over time? (3) Is the nature of science learned better by students if it I embedded within traditional subject matter? (Lederman, 2007).This study tries to answer these contemporary questions, it was applied in a science laboratory course. This course included science subject matters, which was suggested by science educators (Akerson, Abd-El-Khalick, & Lederman, 2000).

The purpose of this study is to explore understanding of PSTs' NOS aspects during the explicit-reflective and inquiry-based laboratory instruction. This study aimed to investigate the effectiveness of inquiry-based laboratory activities, which were designed to develop an understanding of NOS aspects on PSTs. In addition, PSTs' perceptions about NOS aspects before and after the course were explored. This study investigated the following two main research questions:

Research Question 1; To what extend does the explicit-reflective approach, when implemented in the context of inquiry-based laboratory instruction, impact on preservice science teachers' views of NOS?

Research Question 2; What are preservice science teachers' perspectives and experiences related to their learning in the science laboratory course?

1.6 Organization of the Dissertation

This thesis is comprised of five separate chapters. Following this introductory chapter, Chapter 2 provides a review of the literature related to the major constructs examined in this study; scientific literacy, NOS, SI, and laboratory instruction. Chapter 3 provides an explanation of the methodology employed in this study, including the theoretical framework, context of the study, research design, and data collection and analysis procedures. Chapter 4 presents the results of the study in terms of each of the research questions. Chapter 5 concludes with a discussion of the findings and implications for future research and teacher educations/curriculum.

CHAPTER 2

LITERATURE REVIEW

This literature chapter covers the relevant literature about NOS. First, an overview of research about the relationship between scientific literacy and NOS is provided. Next, the studies about the understandings of NOS for preservice teachers and effective teaching methods for NOS are presented. This is followed by an overview of studies about scientific inquiry (SI), science process skills (SPS), and NOS. The chapter is concluded by a summary of studies that specifically address the Turkish preservice teachers' views about NOS.

2.1 Scientific Literacy and the Nature of Science

In science education, it has been emphasized that science should be taught to all students. For the majority of students, science is an indispensable subject that they will use throughout their life and educators need to prepare them for their future lives and careers through a through effective science education. Thus, in light of above emphasis, minorities can also use their science education in order to determine their future careers. This can be insured by improving students' scientific literacy. It is argued that when the number of scientifically literate people in a society is increased, public understandings of science would get better (Driver, Leach, Millar, & Scott, 1996).

There are some dedicated groups in major science associations that aim at promoting the importance of scientific literacy for society (NSTA, 1982). Moreover, NOS has been accepted as being an important component of scientific literacy. As a definition, NOS refers to the values and assumptions inherent in the development and interpretation of scientific knowledge (Lederman, 1992). The NOS is distinct from understandings of the facts and concepts of science. Driver et al. (1996) describe NOS as;

> …ideas which a student has *about* science, as distinct from their ideas about the natural world itself… how the body of public knowledge called science has been established and is added to; what our grounds are for considering it reliable knowledge; how the agreement which characterizes much of science is maintained…. Understanding of the social organization and practices of science, whereby knowledge claims are 'transmuted' into public knowledge, and of the influence of science for the wider culture, and vice versa (1996, p. 13)

In the science education literature, there are different types of arguments as to why enhancing public understandings of NOS is necessary. These are utilitarian, democratic, cultural, economic, science learning, and moral arguments (Driver, Leach, Millar, & Scott, 1996; Thomas & Durant, 1987). The utilitarian argument promotes understanding of NOS, because it is required to make sense of the science and adapt to the technological devices. Moreover, the utilitarian argument maintains that understanding of NOS is important for society, since people encounter science-related problems in everyday life. For example, while making decisions, people need an understanding of scientific knowledge to decide whether a piece of knowledge is appropriate for a given situation. This way, people can construct a judgment about the reliability of the knowledge (Driver, et al., 1996).

In the democratic argument, there is an emphasis on socio-scientific issues. Understanding of NOS is necessary because people should participate in decision-making procedures about socio-scientific issues. In a society, many socio-scientific issues are determined by policy makers. Since these issues often have a science dimension, understanding NOS helps to citizens, who participate in the debates and this way contributes to the decision-making process itself (Driver, et al., 1996).

According to the cultural argument, NOS has an important role to appreciate the value of science as part of a contemporary culture. Understanding of NOS would provide major landmarks in our perception of the natural phenomena and the main figures and events in the history of science (Driver, et al., 1996).

In the moral argument, understanding of NOS promotes people to develop their understandings of norms in the scientific community that embody moral commitments. There are some institutional norms of science, such as universalism and communism. Scientists should deviate from these norms but at the same time, they should identify values to which the public as a whole subscribes (Driver, et al., 1996).

The last argument is about science learning. This argument emphasizes learner' understandings of NOS in order to achieve successful learning of science subject matter. Although there are some debates about this argument, research has showed that understanding of NOS promotes people to better understand science context (Driver, et al., 1996).

All arguments are about public understandings of NOS and related to scientific literacy. These arguments show the importance of NOS understandings from different aspects for developed countries. Most of these arguments support that learners need to be educated by professional educators, who have an adequate understanding of NOS. In most formal education systems, science teachers are responsible to teach NOS. This study has focused on preservice science teachers, who will teach NOS at elementary schools. In the past, several studies that aimed at developing preservice and in-service teachers' understandings of NOS (Lederman, 2007). According to NOS literature, researchers used different teaching methods to improve learners' NOS understandings (Abd-El-Khalick & Lederman, 2000). Below is a summary of these researches.

2.2 Teaching Methods for the Nature of Science

There are important studies in science education literature, where science educators tried to improve learners' NOS views. Two distinct approaches were identified regarding the efforts in promoting the understanding of NOS. These are the implicit approach and the explicit-reflective approach (e.g., Abd-El-Khalick & Akerson, 2004; Akerson, Abd-El-Khalick, & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002; Schwartz, Lederman, & Crawford, 2004).

According to Lederman (2007), the implicit approach proposes "an understanding of NOS is a learning outcome that can be facilitated through process skill instruction, science content coursework, and doing science" (p.851). The explicit-reflective approach suggests, "[U]sing elements from history and philosophy of science and/or instruction focused on various aspects of NOS to improve science teachers' conceptions" (Lederman, 2007, p. 852). According to reviews about NOS teaching, explicit-reflective approach is more effective than implicit approach in improving NOS views among in-service and preservice science teachers (Abd-El-Khalick & Lederman, 2000; Lederman, 2007).

2.2.1 Explicit-Reflective Teaching

In this section there are three important studies related to using the explicit-reflective method to improve learners' NOS views. One of the important studies was done by Akerson, Abd-El-Khalick, and Lederman (2000), who investigated the influence of an explicit-reflective and activity-based approach on pre-service teachers' views of seven NOS aspects. A total of 50 subjects participated in the study, who consist of 25 undergraduate students (23 females and 2 males) and 25 graduate students (22 females and 3 males). The subjects were enrolled in two different sections of a specially designed elementary science methods course. In both sections, the students had similar science backgrounds and were in the first year of their respective programs.

The instruction was applied by the first author for both sections of the methods course. The two sections were taught with the same structure in that the same assignments, readings, and activities were given. During the course, the students were provided with opportunities to reflect on their views of the target NOS aspects. Activities related to NOS aspects were explicitly addressed and subjects were encouraged relating science content and pedagogy to NOS aspects.

An open-ended NOS questionnaire was applied before and after the course to determine students' views about NOS. Totally, 40 students (20 from each section) were chosen for interviews. The interviews were conducted with half of the students (10 from each section were randomly selected) at the beginning and the other half of the students at the end of the semester. During these interviews, the researchers aimed at gaining detailed information about students' views of NOS and clarifying misunderstandings of open-ended NOS questionnaire. During the data analysis, the second and third authors performed data analysis separate interviews from the NOS questionnaire to establish the validity of NOS questionnaire. They completed data analysis as a separate case for each student.

The results of the study showed that most of the students in both sections held inadequate views of target NOS aspects at the beginning of the course. In addition, students' views of NOS aspects were not consistent through seven dimensions. Furthermore, participants' NOS views for seven intended aspects in both groups were not substantially different. At the end of the semester most of the students held satisfactory views of NOS in both groups. Especially, for many aspects of NOS (tentativeness, creative and imagination, observation and inference, theories and laws) students made more gains. However, for some aspects of NOS students made fewer gains such as theory-laden and socio-cultural NOS aspects. The study showed that the explicit-reflective and activity-based approach for NOS instruction was effective to enhance preservice elementary teachers' view of NOS.

Schwartz, Lederman, and Crawford (2004) made another study about NOS. The researchers aimed to answer a question that whether learners can develop NOS conceptions aligned with current perspectives advocated for K-16 learners by engaging in scientific inquiry activities or not. Thirteen students (seven male, six females) participated in the study. They were secondary preservice science teachers enrolled in a fifth-year, Master of Arts in Teaching (MAT) program. This study was conducted during a science research internship course, which was taught by third author.

The internship course included a research component, seminars, and journal assignments. All of the students were assigned to the practicing scientists, who work at the University. During the 10 weeks, the students experienced the authentic research settings for 5 hours a week. Scientists were asked to discuss about their studies with the interns, and if possible, to permit the participants involve in their studies. The journal assignment part was composed of research and reflection sections. For research section, the interns were expected to keep detailed records of their research experiences and to make connections between their research experiences and NOS aspects. In addition, the interns had some questions related to research section; these are consisted of reflection part. All of the participants joined five 2-hour seminars, where NOS aspects were taught by using the explicit-reflective approach. These seminar hours provided chances for the interns to communicate about their research settings with each other. Moreover, the students had opportunities to share their experiences and reflect relationships between NOS and science teaching.

During the data collection, the researchers used questionnaires, interviews, journal entries, and participant observations. A formal NOS questionnaire (VNOS-C) was used to determine students' NOS views both before and after the research intervention. Furthermore, semi-structured interviews were conducted following both applications of the VNOS-C. The first author made observations and took notes during the seminars about interactions between the participants and the instructor, their discussion, questions, and comments. In addition, video records were used to collect data.

All of the data were analyzed and discussed until gaining a consensus among the researchers. For each student data were analyzed to create personal profile, and the authors compared students to illustrate common points across the course. According to the results of the study, students showed substantial development in their NOS knowledge. Many of the students (85%) showed advanced development in their NOS understanding at the end of the study. The researchers also reported that two of them (15%) did not demonstrate any development in their NOS views. According to interviews, the interns endorsed their improved NOS views in their journal entries and emphasized that the seminars were the most beneficial component of their research internship. On the other hand, the research settings were evaluated as having the least direct effect on NOS views by the participants. As a result, the researchers concluded that teaching NOS could be more successful if instructors use the explicit teaching method within an authentic research experience. The researchers stressed that cognitive disequilibrium promoted the interns to find solutions and to gain new information, thus the results were consistent with proponents of conceptual change learning.

Another study about developing NOS aspects was done by Abd-El-Khalick and Akerson (2004). The researchers aimed at investigating the effectiveness of the explicit-reflective NOS instruction. They tried to determine factors that mediated the improvement of NOS views. The sample of this study consisted of 28 preservice elementary teachers (25 female and 3 male), who enrolled in an elementary science teaching methods course. Six of the participants were selected and closely followed during the study by the researchers.

The science teaching method course required participating in 3-hour sections weekly. For intervention of the study explicit-reflective NOS instruction was applied, and the instructor used conceptual change strategies to promote participants' NOS views during the semester. Participants' prior views of NOS were determined using VNOS-B questionnaire at the outset of the study. These views were used for discussion parts during the intervention. In order to introduce participants to the expert science educators' perspectives on NOS, two readings were assigned. Next, during weeks 3-5 of the intervention, subjects completed 11 science activities designed for NOS views. During these activities, participants were encouraged to participate in small group and whole class discussions. Prospective teachers were expected to express their perspectives about NOS views both orally and in writing during the intervention. Moreover, the researchers chose some readings for participants and required reflection papers for each of the readings from the participants.

To collect data the researchers used the open-ended NOS questionnaire (VNOS-B) to reveal participants' pre- and post-instruction NOS views. In addition, semi-structured interviews were conducted with ten participants selected randomly at the beginning and at the end of the study. The researchers used other data sources; including weekly reflection papers, exit interviews, and an instructor's notes. Furthermore, after the fifth week, the researchers detected six participants as a focus group, because their pre-instruction VNOS-B and their first two reflection papers showed greater differences from others. These participants were also interviewed at the end of the semester and asked deeper questions about activities, readings, reflections and their NOS understanding.

According to the results of the study, only a small number of students had informed views of NOS at the beginning of the study. In addition, the study revealed that participants improved their NOS views with regard to all the previously mentioned NOS aspects. The study showed that using the conceptual change strategies, the explicit-reflective NOS instruction developed preservice teachers' understanding of NOS aspects. Only four (14%) participants did not show any changes in their NOS views. The focused group was used to investigate mediating factors for development of NOS understanding. At the end of the analysis, this focus group showed that motivational, cognitive, and worldview factors affected participants' understanding of NOS views.

In summary, three studies are reviewed above, (Abd-El-Khalick & Akerson, 2004; Akerson, Abd-El-Khalick & Lederman, 2000; Schwartz, Lederman, & Crawford, 2004) which are similar to the present study in terms of their goals, methodologies, and samples. The aforementioned studies aimed at developing preservice teachers' NOS understandings and used the explicit-reflective approach as an instruction method. Similarly, the present study intends to improve preservice science teachers' NOS views by applying the explicit-reflective approach. In addition, three studies and the present study use similar methods to collect data, similar questionnaires, interviews, and reflections papers. Nonetheless, there are some significant differences between the present study and others in terms of activities and intervention. The present study was applied in the science laboratory class and activities were designed for inquiry approach, minds on- hands on with together, also activities included science context.

In recent time, science educators have focused on some factors that would mediate understanding of NOS aspects, for example, epistemological beliefs, motivational level, and metacognitive awareness (Abd-El-Khalick & Akerson, 2004); past science experiences, attitudes toward science, self-efficacy, learning dispositions and related general epistemological beliefs, and religious beliefs (Southerland, Johnston & Sowell, 2006).

Recently, Deniz (2007) focused on six factors related to NOS understanding and epistemological beliefs, which are prior conceptions, metacognitive factors, thinking dispositions, science self-efficacy beliefs, motivational factors, and ontological factors. The researcher aimed at investigating the effectiveness of explicit-reflective instruction on preservice elementary teachers' NOS views and epistemological beliefs. An explicit-reflective approach was applied to improve NOS views of 161 preservice elementary teachers who were enrolled in an introductory science course.

During the introductory science course, three main themes were emphasized: science process skills, hypothesis testing, and the nature of matter. Students met in labs two different days in a week and they met another day for lecture. Totally, they spent 5 hours every week. For the first 4 weeks, the instructor focused on the tentative, empirical, inferential, subjective, creative NOS, and the relationship between theories and laws. Students participated in content-generic activities from NOS literature (e.g., The Card Exchange Activity (Cobern & Loving, 1998), Tricky Tracks, Rabbit? Duck?, Young Woman? Old Woman?, Aging President, The Tube, and The Cubes (Lederman & Abd-El-Khalick, 1998) . For hypothesis-testing part, students were engaged in inquiry-oriented lessons such as “A Grave Mistake” (Watercourse & Council for Environmental Education, 2004). Lastly, students participated in “Rutherford’s Enlarged” (Abd-El-Khalick, 2002) activity and a presentation about the history of the atomic theory. In addition, students were assigned some readings about the science education community’s views of NOS aspects. After each activity, students discussed NOS aspects related to class activities. They also they had a chance to write their reflections on the class readings.

In the study, a mixed method approach was utilized. Students’ NOS views and epistemological beliefs about science were detected by applying pre- and post-instruction. According to the results of the study, the explicit-reflective NOS instruction was effective in improving epistemological beliefs and NOS views. Other findings showed that, previous epistemological beliefs and NOS views were related to post-instruction epistemological beliefs and NOS views. Moreover, among six factors only one, thinking dispositions, was detected to be correlated to post-instruction epistemological beliefs.

This study (Deniz, 2007) was an inspiration for the present study. There are some similarities between this study (Deniz, 2007) and the present study. Both of studies are related to the development of NOS understandings. The explicit-reflective approach was applied to improve NOS views in these studies. Especially, during the planning phase of the present study, Deniz’s (2007) provided important ideas, such as using science process skills and laboratory activities to develop students’ NOS views.

The present study was conducted in the science laboratory class, and activities included science context. In the present study, inquiry approach was implemented. Inquiry based laboratory activities were adapted from literature and some of them developed by the researchers. In science education, inquiry approach was utilized to improve learners NOS understandings. In the next section, the relationship between NOS and scientific inquiry is discussed, and some examples of research in this area is reviewed.

2.2.2 Inquiry and the Nature of Science

In science education literature, there are some studies about NOS and scientific inquiry (SI). Scientific inquiry includes science process skills (SPS), which are essential to successful learning in science content matters and relations of intellectual development. Researchers used some techniques to supply connection between conceptions of NOS and SI. Generally, researchers prefer science method courses to train prospective teachers about these conceptions. In this section, some studies are reviewed and the connections to the present study are discussed. At the end of this section, an important study by Sandoval (2003) is reviewed, which emphasizes a paradox regarding using inquiry as a teaching method.

One of the studies about SI was conducted by Gess-Newsome (2002). The author aimed at investigating the impact of the explicit-reflective NOS and SI instruction on conceptions of science in a science method course. Totally, 30 preservice teachers (28 females and 2 males) participated in the study. The participants enrolled in the science methods course, were all in their senior year, and previously completed other science content courses and pedagogical courses.

The instruction was applied by the author for the science methods course. Preservice elementary teachers met 2-hours for a meeting, twice in a week, during the ten weeks. The course especially focused to give students experiences in inquiry based approach, to enhance preservice teachers' understandings of science content, NOS, and SI, and to help students in designing and implementing the inquiry based lesson plans. The researcher showed examples of lesson plans, which focused on how science should be taught. This part of the intervention included combined science content and science processes, and some specific methods for science instruction. Students presented their lesson plans, which were designed for public schools in the last four weeks. Discussions about the effectiveness of lesson plans, methods, and designs had an important part during these presentations.

The researcher collected data using journal questions, which focused on illustrating preservice elementary teachers' conceptions about science teaching and learning during the first five weeks. For example; Define science; What topics, ideas or actions make up science? At the end of the elementary science method course students were expected to create a philosophy of science teaching and learning. After data collection process, the researcher placed students' conceptions into five categories. The product views accepted science as a body of knowledge; the process view defined science as a method of achieving knowledge; blended views included product and process views together; vague answers were listed as unclear; and missing data were labeled as no answer list.

According to the result of the study, the elementary science method course improved students' understanding of NOS and SI conceptions. This intervention developed students' science conceptions from body of knowledge or product, and perfectly blended the views of scientific products and processes. Lastly, the study showed that the explicit teaching method is accepted as a way to enlarge students' understandings of NOS and SI.

Another study about NOS, SI, and science process skills (SPS) was conducted by Abell, Martini, and George (2001). The researchers intended to examine effectiveness of their teaching methods about NOS and SI on preservice elementary teachers' understanding of NOS aspects. The study was conducted in a six-week period at the beginning of the semester in a science methods course. Eleven prospective elementary teachers volunteered to join the study.

The researchers applied the six-week intervention for the two section of the science methods course. The course was designed to improve students' ability to build theories about science teaching and learning. Especially, one of the aims of the course was investigating students' own science learning. To this end, students finished an investigation about the phases of the moon for six weeks. The phases of the moon inquiry activity stressed some of the aspects of NOS; these are scientific knowledge is empirically based, scientific knowledge includes the invention of explanation, and scientific knowledge is socially embedded. During the six weeks the students observed, collected data, recorded these data, participated small and large groups' communications, and kept field notes about the phases of the moon. The instructors used explicit instruction and encouraged the students to write about their investigation and about related aspects of NOS for each week.

Data were collected from students' field notes about moon investigation for each week. In addition, these field notes included students' views about science teaching and learning. Moreover, the researchers wanted from students to write a final reflection, which included summary all the works during the six weeks and their views about teaching the moon phases in elementary science classes. The other data source was interviews with the eleven volunteer students, one of the researchers conducted a one-hour post unit interviews. The researcher tried to deeper understanding about students' moon conceptions, their views about NOS aspects, and their beliefs about science learning and science teaching. During the data analysis phase, the researchers triangulated the data and found common patterns. Next, the researchers used the aspects of NOS in science education literature and standards to analyze the data.

As a result of the data analysis, the researchers concluded that students realized some SPS while doing their investigation, but they did not connect these skills to the aimed aspects of NOS. In addition, students appreciated the importance of social dimensions, but they did not recognize the effects of these dimensions on scientists' works. According to results of the study, the researchers criticized their teaching methods about moon investigation and aspects of NOS. These results showed that the researchers intended to be explicit about teaching at the beginning, but their intervention was more implicit. They emphasized explicitly students' learning processes. However, there were some deficiencies about links between these processes and aspects of NOS. At the end, the researchers recommended some suggestions about explicit NOS instruction and moon investigation for future research.

Sandoval (2003) asserted a different approach about inquiry and NOS for science education. He stressed the importance of NOS as what scientific knowledge is like and how scientific knowledge is constructed. In addition, he emphasized that most recent science reforms promoted inquiry as a method to understand the views of NOS. Inquiry method has some advantages to engage learners in their own efforts to build their scientific knowledge. However, Sandoval claimed that we do not have any indication using inquiry methods in class promotes learners' understanding of NOS. The author depends on two ideas to support his claim. One of them is related to assessment tools, which define students' views about NOS. They do not assess learners' own works to do science. However, assessment tools have commonly goals for professional science. The other idea is related to explicitly epistemic discourse. The author criticized studies, which did not focus on what learners know and how they know them. Moreover, learners did not connect their work to professional science. Sandoval paradox is that "Doing inquiry may be the best way to develop students' ideas about science, but students' ideas about science often interfere with their inquiry" (Sandoval, 2003. p. 1). The author mentioned two possible ways to develop epistemological beliefs through inquiry. One of them is explicit epistemological discourse. According the author applying argumentation connected to scientific practices in class is a suitable method and it is different from didactic instruction. Another way is epistemic tools to structure artifacts and discourse. The author emphasized that epistemic tools promote an explicit discourse about scientific knowledge construction, and this seems to help learners in solving particular problems. In addition, the author suggested that we need more research incorporated instructional approaches and epistemological development for successful inquiry reforms. Furthermore, the author recommended a possible strategy for making this integration: the teachers should ask students to reflect on how the work they do in class relates to scientific work; they should not ask abstract and memorization questions about the experimentation or nature of theories.

The author brought to attention the fact that that although there have been some effective science education reforms, unfortunately little progress has been seen in developing students' understandings of NOS. Moreover, inquiry-based instruction was accepted as a useful tool to develop students' understandings of NOS. However, in literature, there are not conclusive studies to show this change about students' epistemological ideas. On the other hand, the author emphasized that students' background thoughts about science directly affect their inquiry works; this is the so-called inquiry paradox (Sandoval, 2003).

The present study is concerned with this paradox. At the beginning of the study, the researcher tried to describe PSTs' beliefs about NOS. Thus, the researcher applied the Views of Nature of Science Questionnaire Version B (VNOS-B) (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). During the semester, every week, PSTs had written material about NOS and inquiry-based laboratory activity before the laboratory hours. During the activities, PSTs discussed and shared their ideas with other group members in their study groups. After the inquiry activities, every group had opportunities to discuss about their inquiry process and share their results with the whole class. Every week, the researcher prepared a presentation about relations between NOS aspect and inquiry activity. Finally, the PSTs were asked to write their own ideas about NOS aspect and the inquiry activity at the end of the laboratory. The present study tried to solve the inquiry paradox using interconnecting approaches between beliefs about NOS and SI as suggested by Sandoval (2003).

As can be concluded from the above studies, using explicit-reflective method is suitable to improve prospective teachers' understandings of NOS views and SI. Gess-Newsome (2002) showed the relationship between NOS views and SI concepts in a method course. The present study used inquiry-based laboratory activities in the laboratory, where PSTs did experiments and had responsibility of activities. In addition, the current study applied the explicit-reflective teaching instruction. Abell, Martini, and George (2001) stressed that they tried to apply explicitly but their intervention was implicit. Therefore, during the intervention, the researcher checked explicit-reflective process for this present study. Moreover, Abell, Martini, and George (2002) concluded that prospective teachers realized SI conceptions but they did not connect these with NOS conceptions. In the present study, the researcher emphasized the relationship between NOS and SI. During the intervention, every week, presentation included this relationship and at the end laboratory activities, PSTs were asked to write this relationship in their weekly reflection papers.

2.3 Studies of Turkish Preservice Teachers' Understanding of NOS

Turkish elementary science curriculum have been revised and re-designed to include goals and objectives related to NOS (MoNE, 2004). Turkey has more than a hundred universities, most of which include faculty of education, with many science education researchers. These researchers try to educate professional science teachers according to new elementary science curriculum. In this section, several studies related to understandings of NOS among preservice teachers in Turkey are reviewed.

One of the studies was conducted by Tasar (2006). The aim of this study was to investigate preservice middle school science teachers' understanding of NOS by using a vignette. A total of 36 students participated in the study, participants gender was not specified. They were enrolled in a "History and nature of science" course, which included 16th and 17th century scientific revolution and its historical background. All of the students participated in the study had similar science backgrounds.

Instruction was applied in spring semester by the researcher in his institution. During the course the researcher used Turkish translations of two books; The Construction of Modern Science (Westfall, 1977), and The Double Helix (Watson, 1969).

The researcher used qualitative and quantitative methods to collect data. At the end of the semester, students were asked to answer the open-ended questions about important characteristics of science based on their readings and to write some examples. Following that, students were distributed a sheet that included a vignette, which was from a popular science magazine, and a question was directed to the students regarding the vignette about scientific facts, concepts, theories, laws etc. Students were expected to identify and explain their answer in writing. The quantitative part included the 48-item Nature of Scientific Knowledge Scale (NSKS). The Turkish version of this scale was applied. These data were analyzed by the researcher, who formed categories and codes from students' answers for qualitative analysis.

The result of the study showed that most of the students separated scientific concepts from each other. However, many of the students accepted a false hierarchical relationship among scientific concepts (facts, hypothesis, theories, and laws). Students showed their views about tentativeness of scientific knowledge, but they hold misconception about subject to change of laws. Other types of scientific knowledge were seen changeable. The author concluded that vignettes can be used to determine students' understandings of NOS concepts. In this study, the researcher did not focus on NOS aspects explicitly.

Another study was conducted by Akgul (2006). The purpose of this study was to explore preservice elementary teachers' understandings of teaching science in an inquiry-based learning environment. A total of 35 preservice science teachers participated in the study. They were enrolled in a "Teaching science" course.

Instruction was applied in spring 2001 semester by the researcher. The researcher has a strong background in the inquiry-based teaching and learning. She focused on some examples about inquiry-based teaching in this study. The intervention was designed to inform students about an inquiry-based learning method and its environment, and to develop students' understandings of NOS in teaching science.

The researcher used a qualitative method to collect data during the intervention. In order to define participants' pre-philosophy statements at the beginning they were asked some open-ended questions about nature of science. To cite a few of these questions; What is science? Who does science? etc. Moreover, some questions were related to students' and teachers' roles in an inquiry-based learning environment and in-class activities. Similar questions were asked at the end of the study to determine participants' post-philosophy statements. The author did not mention whether these questions developed by the author or adopted from another scale. Other instruments the researcher used were Nature of Science Card Game and reflection on a scenario, which an inquiry-based learning and teaching environment was exemplified in the course.

The researcher performed detailed data analysis. As a result of the data analysis, six main assertions were formed. First, students defined science as a static body of facts. Second, students perceived teachers' role as transmitting scientific facts to their students. Third, students accepted students' role as to receive scientific knowledge given from their teachers. Last three assertions were related to the effectiveness of inquiry-based science course, and the researcher used pre and post philosophy statements. Forth, the study showed that inquiry-based science course did not make a significant contribution to students' understandings of NOS. Fifth, at the end of the course student showed a significant development of understandings of science teachers' role. Lastly, the study showed that inquiry-based science course had a positive effect on prospective science teachers' understandings of students' role in the classroom environment.

One recent studies about NOS conceptions was conducted by Celik and Bayrakceken (2006). The study aimed to detect preservice teachers' views of some aspects of NOS and to assess the effects of a Science, Technology, and Society course. Totally 213 students participated in the study (108 male and 105 female). These students were selected from three different Primary Teacher Training departments (169) and a class from Primary Science Teacher Training department (44). They were enrolled in four different sections of a Science, Technology and

Society (STS) course. In terms of their science backgrounds of the four sections were similar, because primary teachers had a mixed science and social background, and all of the students were in their final year in their teaching training program.

Instruction was applied by the second author, who is a science education professor. Four sections were taught using the same structure, with the same assignments, the same readings, and same the activities. The STS course was applied for three hours in a week and it spanned 14 weeks. The researchers mainly aimed at promoting students' understanding of NOS views, developing SPS, and understanding interactions among science technology-society. The STS course was student-centered, was free of asking questions, was include peer group discussions, and included inquiry-based activities, which were SI activities and students engaged in these activities. The instructor used explicit-reflective method for the intervention.

The researchers selected thirteen items, which were accepted as related to NOS aspects by VOSTS (Views of Science, Technology and Society) developed by Aikenhead, Ryan, and Fleming (1989). The items were translated from English to Turkish by the experts, and these items were administered 20 preservice teachers for the pilot study. The test was applied before and after the course to determine the development of students' views about NOS. For the data analysis, the researchers used qualitative and quantitative approaches to address the research questions.

The data analysis showed that students in all of the sections held inadequate views of target NOS aspects at the beginning of the STS course. For example, most of the students accepted scientific knowledge as facts, which do not change and thought that scientists do not use their imagination and creativity during scientific investigation. In addition, they viewed that there is one scientific method, which has a hierarchical sequence. At the end of the STS course, students' improved their understandings of the characteristics of science, the scientific models, and the scientific method. Moreover, students showed improvement for determining relationships among scientific hypothesis, theories, and laws. However, in some characteristics of science especially those related to scientists, the researchers did not find any indication of improvement. Moreover, the researchers noted that the most important result of this study was that the development students' views of NOS can be achieved in large classes. Lastly, this study indicated that explicit-reflective and activity-based approach to NOS instruction was effective to enhance students' understandings of NOS views.

As can be concluded from the above studies, Turkish preservice teachers have inadequate conceptions about NOS similar to U.S. preservice teachers. Additionally, using explicit instruction seems to be more effective in improving Turkish preservice teachers' conceptions about NOS than implicit instruction. Furthermore, there is a variety of explicit methods, including, hands-on activities and SI, projects, and historical vignettes have been shown to be effective. These activities can be used in a variety of courses, including Science-Technology-Society, history of science courses, and teaching methods courses. Therefore, the above studies support using explicit instruction with Turkish preservice teachers in the context of a laboratory science course as a possible means of improving their conceptions about NOS.

The review of important studies from science education literature showed that understanding NOS is an important component of scientific literacy. In addition, there are many successful studies about the development of learners' understanding of NOS. Moreover, it has been shown that SI is an effective instruction method to change learners' NOS views. Lastly, this study was conducted in Turkey and studies from Turkey were similar regarding understanding of NOS with other western countries in science education literature.

CHAPTER 3

METHOD

The method chapter presents information about design of the study, data collection, data analysis, and the researcher's biases.

3.1 Design of the Study

This part of the chapter explains the design of the present study and how it aligns with the theoretical framework. First, the study design and research questions were addressed. Next, participants, context of the study, and data collection and analysis were provided. Validity and reliability issues were presented in data collection and analysis parts and the researcher's biases were presented in the end.

The design of the study was qualitative and exploratory in nature (LeCompte & Priessle, 1993; Marshall & Rossman, 2006), which provides the importance of contexts, settings, and in-depth understandings of participants' perspectives. The design was utilized by many researchers who were interested in investigating participants' understandings of NOS views (e.g., Abd-Abd-El-Khalick & Akerson, 2004; Akerson, Abd-El-Khalick, & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002; Schwartz, Lederman, & Crawford, 2004). The present study focused on the meanings that PSTs attributed to the NOS aspects. Data collection procedure was continuous and spanned the whole semester in which participants were enrolled the Laboratory Application in Science II course.

The intent of this study was to explore understandings of PSTs' NOS aspects during the explicit-reflective and inquiry-based laboratory instruction. In the initial phase of the study, the researcher collected qualitative data with open-ended questionnaire to explore PSTs' NOS views. Then, during the semester, reflection papers were collected to understand PSTs' experiences with the intervention and to see development about each NOS aspect. At the end of the semester, qualitative questionnaire and interviews were conducted to determine the impact of the explicit-reflective and inquiry-based laboratory instruction.

This study investigated the following research questions:

Research Question 1; To what extend does the explicit and reflective approach, when implemented in the context of inquiry-based laboratory instruction, impact on preservice science teachers' views of NOS?

Three sub-questions;

(1) Do preservice science teachers associate the inquiry-based laboratory activities with aspects of NOS?

(2) How do preservice science teachers' views change as a result of participating in these inquiry-based laboratory activities?

(3) Do preservice science teachers link among the separate aspects of NOS?

Research Question 2; What are preservice science teachers' perspectives and experiences related to their learning in the science laboratory course?

Two sub-questions;

(1) What are preservice science teachers' perspectives about factors that might affect their understanding of NOS aspects?

(2) What are preservice science teachers' perspectives about future science teaching?

3.2 Participants

All 52 PSTs enrolled in the Laboratory Application in Science II course offered by the faculty of education consented to participate in the study. At the beginning of the course, 45 out of 52 PSTs agreed to join the study on voluntarily. Basis of the 45 PSTs, 34 were female and 11 were male with a mean age of 22.8 years (ranging from 21-29). All of the PSTs were juniors and had the same science major background. During the spring 2008, this course was taught in two different sections. The first section contained 27 PSTs and they met 4 hours per week (on Tuesdays). The second section contained 25 PSTs and they met 4 hours per week (on Thursdays). The course hours were the same for both sections from 1:40 pm to 5:30 pm. At the beginning of the semester, PSTs selected their own section and formed their study group (six group per section, each group included generally 4-5 PSTs).

3.3 Context of the Study

The Elementary Science Education (ESE) program aims to train science teachers with a good self-image, a sense of humor, and a curiosity in helping their students to understand science properly. Science teachers graduated from this department are expected to represent a true model for their students in terms of their personal and professional life. The program also aims to educated science teachers, who know how students learn science, consider human rights, democracy, and ethics while teaching. In addition, the program focuses on contemporary model of science teacher according to recent education reforms (METU, 2009).

Preservice science teachers in the ESE degree program at the Middle East Technical University (METU) complete science coursework in biology, chemistry, physics, and mathematics during their first two years of university education. In their third year, all students in the program are required to enroll in Laboratory Application in Science I for the first semester and Laboratory Application in Science II for the second semester. During this year, these students also enroll in courses directly related to methods of science teaching (e.g., Methods of Teaching I and II, Instructional Technology and Materials Development, Science Technology and Society, School Experiences). In addition to these courses, the students take pedagogical courses as a requirement of their program (e.g., Classroom Management, Measurement and Assessment, Educational Psychology).

Laboratory Application in Science I, preservice science teachers were enrolled into one of the two sections of this course in fall semester. All of the laboratory activities were conducted in the same science laboratory class throughout the semester. As a teaching method, guided inquiry teaching approach was implemented. PSTs met four hours a week. The course program was designed to help PSTs understand the nature of scientific inquiry by engaging them in “doing science” rather than by merely reading about scientific concepts and memorizing scientific facts. The content of the course emphasized science process skills (SPS) and mathematical skills. Moreover, the course provided the use of theories and models that are fundamental for learning the various science disciplines (physics, chemistry, biology). Laboratory Application in Science I began with some of the SPS (observation, classification, measurement, inference, prediction, variables, etc.) and moved into the mathematical skills (graphs, large and small numbers, problem solving, and proportionality).

This study was carried out during the Laboratory Application in Science II course, which is offered in spring semester. This course was coordinated by the researcher and faculty members, and taught by doctoral teaching assistants. The course was re-designed and extended to provide meaningful and practical experiences in science and to help PSTs’ gain deeper understanding of NOS. The new design promoted PSTs’ active involvement in scientific activities and discussions. Table 3.1 provides an overview of the organization of a typical laboratory activity for each class session.

Table3.1. Organization of Weekly Course Activities

Week	Time	Content
1	15-20 minutes	Quiz, related to laboratory activities and the aspect of Nature of Science
	2 hours	Laboratory activities related to the aspect of Nature of Science
	1 hour	Presentation and discussion about results of activities and relationship nature of science aspect.
	30 minutes	Reflection paper, related to laboratory activities and the aspect of Nature of Science

The Laboratory Application in Science II course provided opportunities for PSTs to participate 2-hour lab sessions followed by an hour presentation and discussion part at the end of the laboratory each week. Moreover, PSTs took a quiz included two or three questions related to inquiry-based laboratory activities and the aspect of NOS at the beginning of the laboratory section. At the end of the laboratory section, all of the PSTs wrote reflection paper included three questions related to laboratory activities, SPS, and the aspects of NOS.

3.4 The Laboratory Application in Science II

This part includes foundations of the study. These are basics of the laboratory course; focused on NOS aspects, explicit-reflective instruction, dimensions of effective teaching of NOS, teaching NOS through inquiry, and science process skills (SPS) focused on this study.

3.4.1 Aspects of NOS Focused on in the Course

During the spring semester, the instructors focused only one aspect of NOS each week. There are some debates about defining NOS; however, in this study the researcher used aspects of NOS identified by science educators to be relevant to K-16 education and about which there is a consensus (Abd-El-Khalick & Akerson, 2004; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Schwartz, Lederman & Crawford, 2004). These include (1) The Empirical Nature of Scientific Knowledge; scientific knowledge is based on evidence and observations of the natural world. (2) Observations, Inference, and Theoretical Entities in Science; scientific knowledge includes observation and inference which are different. Observations are gathered through human senses and inferences are interpretations of those observations. (3) Scientific Theories and Laws; theories and laws are different kinds of scientific knowledge and one does not become the other. Laws describe observed or perceived relationships in nature. On the other hand, theories are inferred explanations for natural phenomena and mechanisms for relationships among natural phenomena. (4) The Theory-Laden Nature of Scientific Knowledge; scientific knowledge is theory-laden, scientists' theoretical and disciplinary commitments influence their works. (5) The Tentative Nature of Scientific Knowledge; scientific knowledge is never absolute or certain, scientific knowledge is subject to change with new observations and with the reinterpretations of existing new knowledge. (6) The Creative and Imaginative Nature of Scientific Knowledge; scientific knowledge is created from human imaginations and logical reasoning, this creation is based on observations and inferences of the natural world. (7) The Social and Cultural Embeddedness of

Scientific Knowledge; science affects and is affected by the various elements and intellectual spheres of the culture in which it is embedded. These elements include, but are not limited to, social fabric, power structures, politics, socioeconomic factors, philosophy, and religion. During the spring semester, PSTs did an activity related to only one aspect of NOS for each week.

3.4.2 Explicit and Reflective Instruction

In this study, the explicit-reflective teaching method was utilized to enhance PSTs' NOS aspects. In science literature, there are three common approaches to develop students' views of NOS, and these are historical, implicit, and explicit-reflective. There is much research in this area showing that the explicit-reflective approach is more powerful to improve learners' NOS views (e.g., Abd-El-Khalick et al., 1998; Abd-El-Khalick & Lederman, 2000; Akerson et al., 2000; Shapiro, 1996). Khishfe and Abd-El-Khalick (2002) defined explicit-reflective as;

> An explicit and reflective approach emphasizes student awareness of certain NOS aspects in relation to the science-based activities in which they are engaged, and student reflection on these activities from within a framework comprising these NOS aspects. (Khishfe & Abd-El-Khalick, 2002, p.555)

In the same study, the authors emphasized that understanding NOS is related to cognitive instructional outcomes, therefore, it should be intentionally aimed and planned. As a term, "explicit and reflective'' does not refer to didactic teaching strategies (Khishfe & Abd-El-Khalick, 2002). In line with these recommendations, we intentionally planned instruction and assessment of PSTs' ideas about NOS as part of the laboratory course.

In this study, the researcher developed and/or adapted some laboratory activities related to focus on the aspects of NOS for each week. While adopting laboratory activities, the researcher used some existing activities for teaching NOS literature, for example; black box activity, activities related to fossils, and evolution activities (Bell, 2008; NAS, 1998). On the other hand, while developing new inquiry-based laboratory activities, the researcher utilized science textbooks and science contexts such as, photosynthesis, germination, gases, electrolyzes, evolution, buoyancy.

To ensure the validity of the each laboratory activities developed for this study, besides using the available literature, the researcher also took the expert opinion. For this purpose, the developed inquiry-based laboratory activities were examined and reviewed by science educators and researchers who have expertise in researching and teaching the nature of science. One of the educators, is an Associated Professor in the Department of Elementary Science Education at the Middle East Technical University, and her suggestions were related to feasibility of activities and similar activities from her method courses. Another is an Assistant Professor in the Department of Learning, Teaching, & Curriculum at the University of Missouri, and also she is the co-advisor for this study. She contributed several power-point presentations that could be used to enrich explicit discussion of the nature of science. The third is an Assistant Professor in the Department of Elementary Science Education at the Marmara University, and his suggestions were related to embedding nature of science instruction in the context of the laboratory activities. The last one is an Associated Professor in the Department of Elementary Science Education at the Middle East Technical University. She also serves as the advisor for present study.

Table3.2. Aspects of the Nature of Science and Corresponding Laboratory Activities

Week	Nature of Science Aspect	Laboratory Activity
1-2	The Empirical Nature of Scientific Knowledge	--- Germination of a Seed (developed by the researcher, 2008); this activity was a science project for two weeks, participants tried to find which variables affect the rate of germination. --- Photosynthesis (adapted from, Baruch, 2008); for this activity participants formed groups and designed investigations to determine which variables affect photosynthesis.
3	Observations, Inference, and Theoretical Entities in Science	--- Black Box! (adapted from Lederman & Abd-El-Khalick, 1998); in this activity participants observed a black box into which an amount of water was poured, and double that amount exited the box. Students developed models to represent what they believed was inside of the black box.
4	Scientific Theories and Laws	--- Boyle-Mariotte and Gravity Laws (develop by the researcher, 2008); for this activity every group chose one law and related theory, and groups formed different experimental designs based on those.
5	The Theory-Laden Nature of Scientific Knowledge	--- Evolution Theories! (adapted from NAS, 1998); in this activity participants had the same data but two different theories about evolution, and they reached different conclusions at the end of the activity.
6	The Tentative Nature of Scientific Knowledge	--- Age of Fossils (developed by the researcher, 2008); to complete this activity every participant was given some fossil fragments, and according to given information participants tried to decide the fragments' ages.
7	The Creative and Imaginative Nature of Scientific Knowledge	--- Real Fossils, Real Science (adapted from Bell, 2008); in this activity each group was provided different fossil fragments, and was asked to draw what they believed the entire fossil looked like.
8	The Social and Cultural Embeddedness of Scientific Knowledge	--- Which Water! (developed by the researcher, 2008); for this activity participants formed groups and were asked to role play groups in society with different needs. Each group then setup an investigation to explore different properties of water related to their needs.

She contributed all of the steps development laboratory activities and re-designing Laboratory Application in Science II. Moreover, she gave feedback about inquiry-based laboratory activities' validity. Table 3.2 provides overview of the target nature of NOS aspects addressed each week and names of activities.

While conducting this study, each week PSTs were given a laboratory sheet prior to class. Each laboratory sheet started with a reading text about the aspect of NOS that is focused on in that week. The reading text introduced PSTs to the particular aspect of NOS prior to each laboratory activity, providing them with a conceptual framework for interpreting scientific investigations. Before the inquiry-based laboratory activity every week, PSTs took a quiz included two or three questions related to activities and the aspect of NOS at the beginning of the laboratory section. All of the quizzes were presented in Appendix D. Therefore, this part had an important role for teaching NOS explicitly.

At the end of the inquiry-based laboratory activity, there was an hour in the organization of each course session for a week, focused presentation, and discussion about results of activities and relationship NOS aspect. At the beginning of this part, there was a power-point presentation to reflect science educators' and the researchers' NOS views (e.g., Lederman et al., 2002; Schwartz et al., 2004). This part was addressed using the explicit-reflective NOS instruction. In both of the explicit sections, PSTs were engaged in reflective discussions of the target NOS aspects followed by the inquiry-based laboratory activities. For example, at the end of the "evolution theories" (week 4) activity different groups although had same data set they reached different conclusions. For this reason, they were surprised, and groups tried to explain this difference. At the end of the laboratory section, PSTs wrote their reflections about laboratory activities, SPS, and the targeted aspect of NOS. The explicit-reflective NOS focused the seven target NOS aspects as defined the Table 3.2. The researcher explained NOS aspect and managed discussion among groups every week.

3.4.3 Dimensions of Effective Teaching of NOS

In science education literature, there are many studies emphasized the importance of instructors for teaching NOS (Abd-El-Khalick, Bell, & Lederman, 1998; Abd-El-Khalick & Lederman, 2000; Bartholomev, Osborne, & Ratcliffe, 2004; Lederman, 1999). These studies showed proper NOS teaching require not only knowledge of NOS but also qualified teachers and accurate teaching methods. In their study, Bartholomew, Osborne, and Ratcliffe (2004) identified five dimensions related to teacher perspectives for teaching nature of science explicitly. These are (1) Teachers' knowledge and understanding of the nature of science, (2) Teacher's conceptions of their own role, (3) Teachers' use of discourse, (4) Teachers' conception of learning goals, and (5) The nature of classroom activities (Bartholomew, Osborne, & Ratcliffe, 2004). In the section that follows, we discuss the teaching of NOS, that is, our implementation of the laboratory activities according to these five dimensions.

In the first dimension, Bartholomew, Osborne, and Ratcliffe (2004) defined a line from "Teachers are anxious about their understanding" to "Confident that they have a sufficient understanding of NOS." In the present study, there were two laboratory sections and three different people to implement the study. One of them was the researcher and two of them were research assistants from the department of elementary science education. They were selected and accepted to join for this study as instructors at the beginning of the semester. Each instructor had the responsibility of one section together with the researcher. Both research assistants and the researcher had important roles as instructors. Both research assistants wanted to be instructors for this course at the beginning of the semester, and they took some courses related to NOS before. They graduated from elementary science education department. Every week the researcher and the instructors met on Monday from 1:00 pm to 4:00 pm to discuss the specific NOS aspect and tried to develop the instructors' understanding of these aspects. About first dimension, it can be said that, the instructors were close to "Confident that they have a sufficient understanding of NOS."

In the second dimension, the authors defined a line from "Dispenser of knowledge" to "Facilitator of learning." During the meeting hours on every Monday, the researcher and the instructors discussed the laboratory activities and possible questions that would be confronted with during the intervention. The researcher joined the two sections and observed the instructors, and when PSTs ask questions, the instructors generally helped them find answers by themselves, and did not answer students' questions directly. For the second dimension, it can be said that, the instructors were close to "Facilitator of learning."

For the third dimension the authors defined a line from "Closed and authoritative" to "Open and dialogic." This dimension generally was related to the researcher because in both sections, there were discussion parts at the end of the laboratory activities and this part was managed by the researcher. In this part, the researcher asked open questions, not simple confirmatory yes-no questions, and expected deep explanation from PSTs. Moreover, under the control of the researcher, the groups in the laboratory had an opportunity to discuss their results with each other. About third dimension, it can be said that, the researcher was close to “Open and dialogic.”

In the fourth dimension, the researchers defined a line from “Limited to knowledge gains” to “Includes the development of reasoning skills.” In this study, PSTs completed laboratory activity sheets using science process skills. These laboratory sheets included some questions related to observing, classifying, hypothesizing, experimenting, measuring, etc. While completing the laboratory activities, PSTs used these skills and answered the related questions. For the fourth dimension, the instructors and PSTs fallowed the designated laboratory sheets, therefore, it can be stated that the instructors were close to “Includes the development of reasoning skills.”

In the fifth dimension the authors defined a line from “Student activities are contrived and inauthentic” to “Activities are owned by students and are authentic.” In the current study every week, PSTs had a nature of science aspect and a blank laboratory sheet including only some directions. In the present study, PSTs were expected to develop their own activities and define their specific directions. Most parts of the laboratory sheets were formed according to PSTs’ individual creativity. About the fifth dimension it can be said that the nature of classroom activities were close to “Activities are owned by students and are authentic” because of the structure of the laboratory sheets. Based on all of these dimensions, it can be said that this study was conducted using the explicitly reflective method aiming to develop PSTs' views of NOS.

In addition to these five dimensions, in this study conceptual change was included the design of instructional interventions. This part includes information about how teaching matched with the conceptual change method guidelines before mentioned. First, every week before the laboratory, PSTs were given laboratory sheets including basic readings about more informed views of the NOS aspects. This part of the study intended to elucidate and make PSTs' and the researchers' NOS ideas an explicit part of classroom discourse. Second, during the intervention, PSTs were engaged in the laboratory activities related to views of NOS. At the end of the activity, each group discussed and completed their laboratory sheets. In addition this at the end of the instructor's presentation, all groups shared and discussed their results with other groups in the laboratory class. This part was related to our explicit reflective approach to NOS instruction. Third, every week at the end of the laboratory activities and discussions PSTs were expected to write reflection papers, which include three open-ended questions related to the laboratory topics and discussions.

3.4.4 Focus on Scientific Inquiry and Science Process Skills

Engaging students in inquiry-based activities is an opportunity to develop their understanding of NOS (NRC, 2000). In order to complete inquiry-based laboratory activities, PSTs need to use their science process skills (SPS). The relationship between scientific inquiry and SPS was described by NRC (1996) as during scientific inquiry students should combine SPS and scientific knowledge to develop their understanding of science. In this study, SPS were classified in two different forms; these are Basic Science Process Skills and Integrated Science Process Skills. Basic SPS consist of observing, inferring, measuring, communicating, and classifying. Integrated SPS comprise of controlling variables, defining operationally, formulating hypotheses, interpreting data, and experimenting. Definitions of basic and integrated science process skills are presented in Table 3.3.

Table3.3. Science Process Skills

Basic Science Process Skills
Observing; the process of gathering information about objects and events using the all appropriate senses
Measuring; quantifying the variables by using variety of instruments and standard or nonstandard units
Classifying; a process that is used by scientists to categorize objects based on their general characteristics
Inferring; developing possible conclusions about observations while using prior knowledge.
Communicating; essential to all human endeavors and fundamental to all scientific work.
Integrated Science Process Skills
Controlling variable; one of the essential skills for managing the variables of a scientific investigation. Establishing accurate results can be achieved when these variables are identified and controlled carefully.
Defining operationally; a skill that describes boundaries of things to be considered in a scientific investigation. For different disciplines the defining operationally can be refer different things.
Formulating hypotheses; a statement about a possible relationship in the natural world that might be found through scientific

investigations. Hypothesizing should be based on accurate observations or inferences.

Interpreting data; involves some other SPS, for instance, making predictions, inferences, and hypotheses from the data collected in an investigation.

Experimenting; is the process that encloses all of the basic and integrated processes.

Source; (Abruscato, 1995; Carin, Bass & Contant, 2005).

The new design Laboratory Application in Science II included inquiry-based laboratory activities every week. In this course, PSTs had the chance to be actively involved in scientific activities and discussions. Every week PSTs had laboratory sheet, which included activity related to NOS aspect. PSTs completed these laboratory sheets using their SPS. For example, while completing these laboratory sheets PSTs were confronted with some directives such as:

- State your group purpose
- State your group hypothesis
- Define your manipulated and controlled variables and write in the below table
- Set up your experimental design
- Collect data (observation, measurement), and draw a data table
- What is your observation?
- State your group inference about structure in the Black Box
- Compare the human DNA to the chimpanzee
- Please classify these fossils for six classes, and draw a sample for each class in the below cells

- Please make a detailed diagram of it; the diagrams may be larger than the actual fragments

All of the laboratory activities were presented in Appendix B.

During the laboratory classes, PSTs were engaged in the laboratory activities related to views of NOS during the semester. Each PST in every group was expected to complete her/his laboratory sheets. While completing the sheets PSTs asked questions and discussed their tasks with each other. Furthermore, at the end of the instructor's presentation, all groups shared and discussed their results with other groups in the laboratory class. Thus, PSTs joined small-group and whole-class discussions each week.

3.5 Data Collection

This part of the method chapter includes some information about data collection procedures and description of instruments. First, data collection procedures which instruments were used, when they were applied and for which research questions were indicated. Then, detailed information was given details about data collection procedures and instruments, which are interviews, class artifacts, and questionnaires.

3.5.1 Data Collection Procedures and Description of Instruments

In this study, all of the data were collected by means of interviews, PSTs' reflection papers, and a questionnaire. The data was collected during the Laboratory

Application in Science II course. Table 3.4 lists the research questions, timeline, and the instruments used for each question.

Table3.4. Research Questions and Instruments

Main Research Questions	**Instruments & Timeline**
To what extend does an explicit and reflective approach, when implemented in the context of inquiry-based laboratory instruction, impact preservice science teachers' views of NOS? Three sub-questions; (1) Do preservice science teachers associate the laboratory activities with aspects of NOS? (2) How do preservice science teachers' views change as a result of participating in these laboratory activities? (3) Do preservice science teachers link among the separate aspects of NOS?	VNOS-B Pre- and Post-test were applied at the beginning and at the end of the intervention. Interviews were conducted at the end of the intervention. Reflective Papers were written by participants every week after the activities during the intervention.
What are preservice science teachers' perspectives and experiences related to their learning in the science laboratory course? Two sub-questions; (1) What are preservice science teachers' perspectives about factors that might affect their understanding of NOS aspects? (2) What are preservice science teachers' perspectives about future science teaching?	Interviews were conducted at the end of the intervention. Reflective Papers were written by participants every week after the activities during the intervention.

3.5.1.1 Interviews

One of the qualitative data sources was interviews with PSTs. At the end of the course, 45 out of 52 PSTs agreed to join the interviews on voluntarily. Basis of the 45 interviewees, 34 were female and 11 were male. The interviews were conducted to gain deeper information about PSTs' views on NOS, SPS, and the laboratory activities. During the interviews, a semi-structured interview protocol was used. The interview questions focused on the activities and NOS aspects used each week. The interview questions were designed by the researcher. Feedbacks about the interview' questions were obtained from the supervisor of the study and another educator, and then the questions were revised.

For example, the questions related to the first laboratory class were;

- Is there any relationship between scientific knowledge and experimentation-observation?
- Can you explain your answer with an example from the first laboratory class?
- Is there any relationship among nature of science, science process skills, and scientific knowledge?
- Can you give an example related to science process skills used in the first laboratory class?

Another example, for the questions focusing on the second laboratory class were;

- Is there any relationship between scientific knowledge and observation-inference?
- Can you explain your answer with an example from the second laboratory class?
- Is there any relationship among nature of science, science process skills, and scientific knowledge?

- Can you give an example related to science process skills used in the second laboratory class?

The interview protocol was presented in Appendix C.

3.5.1.2 Class Artifacts

The other data source was PSTs' written reflections. Each week at the end of the laboratory activities PSTs responded to three open-ended questions. These questions were related to that week's topic and discussions. Each PST wrote seven reflection papers during the semester. The reflection questions were prepared by the researcher and under the supervisor of the dissertation. The reflection papers were collected from the instructors from two sections in the laboratory. These three questions were the same related to each week. For example on the first week;

- Explain the aspect of NOS (Empirical basis; scientific knowledge is based on evidence and observations of nature) in your own words. Please relate the aspect of NOS to the experiment that you designed (conducted) this week.
- Write the basic and integrated science process skills that you used to conduct the photosynthesis and Germination Experiment.
- What do you think about the role(s) of SPS to understand the aspect of NOS?

Each of the reflection sheets were presented in Appendix E.

3.5.1.3 Questionnaire (Qualitative)

The *Views of Nature of Science Questionnaire Version B* (VNOS-B) is a seven-item open-ended questionnaire developed by Lederman, Abd-El-Khalick, Bell, and Schwartz (2002).

The researchers revised some items of the VNOS-A (Lederman & O'Maley, 1990) to assess PSTs' views of the NOS. The VNOS-B questionnaire includes seven items related to science teachers' views of the tentative, empirical, creative, theory-laden, socially cultural, and also the function of and relationship between theories and laws, and distinction between observations and inferences. After the development of this questionnaire, the researchers investigated the construct validity of the VNOS-B. According to this study, the VNOS-B effectively differentiates between experts' and novices' views of NOS (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002).

The questionnaire was used first at the beginning of the semester to determine PSTs' NOS views, and was applied again at the end of the semester to find out changes in PSTs' NOS views. Pre and post administration of the VNOS-B were in the laboratory class, two instructors applied their sections. A few PSTs completed the questionnaire out of laboratory class. The questionnaire was presented in Appendix A.

3.6 Data Analysis

All of the data were analyzed at the end of the course, because the researcher tried to avoid some prejudgments, which would affect the study. The VNOS-B questionnaire, reflection papers, and interviews were analyzed.

3.6.1 Analysis of VNOS-B Data

The PSTs' responses to the VNOS-B were word-processed and entered into the NVivo 8 qualitative data analysis software (QSR International, 2008).

A three-stage data analysis technique was devised. The unit of analysis was a statement, defined by Palmquist and Finley as "a paragraph, group of sentences, sentence or phrase that contained a single unambiguous theme about the nature of science" (1997, p. 600). Some examples from preservice teachers' VNOS-B responses included: "Yes, there is a difference between scientific knowledge and opinion. Scientific knowledge is supported by evidence, theories, and laws," "Yes, the theory can change. These changes cause the development of science. We can learn each developing theory," and "Because astronomers have different background knowledge, also they have different beliefs." During the first stage of data analysis, I assigned codes relevant to the aspect of NOS addressed in PSTs' statements (such as, empirical, creative, and subjective). In the second stage of the analysis, all statements assigned to a particular code (e.g., creative) were reviewed and coded in further detail to capture PSTs' views considering that aspect (e.g., designing experiments involves the use of creativity). In the third stage of the analysis, all statements were categorized to find out whether they matched the contemporary views of science (as described in the literature review and reforms) or traditional "myths" or "misconceptions" about science, or if they were a mix of contemporary and traditional views. Consequently, in this study all of the statements about NOS views were classified as inconsistent, transitional, and consisted with current reforms. At the beginning of coding process, a start code was utilized, but the start code was dynamic not static. When new themes and ideas emerge, they were added or primary codes were modified. All of the statements were coded according to Lederman et al. (2002) and Hanuscin (2009). According to Lederman et al. (2002), inconsistent coding statements are naïve views. As for the transitional coding statements, they include some but not all informed views. However, consistent coding statements are suitable views according to recent reforms. Appendix F represents these inconsistent, transitional, and consistent views.

All statements could be coded within this framework. Yet, there were a number of instances in which statements provided evidence of a link made by the PSTs between two or more different aspects of the nature of science. For example, "Science and art are related with each other. Science is subjective, because scientists use their creativity to reach scientific knowledge. Similarly, artists also use their creativity and imagination." As Abd-El-Khalick emphasizes, "… articulating informed views of certain NOS aspects might not reflect an accurate, overarching, and consistent framework" (2003, p. 54). Therefore, it was important to identify these instances during the coding process. For instance, in the above statement, one of the PST suggested a relationship between subjectivity and creativity. In this case, a code was created as "subjectivity-creativity" to note this link.

3.6.1.2 Reliability of the Coding

All of the process analyzing data, defining statements, deciding themes, and assigning codes were validated through extensive discussions with the researcher and the co-advisor, who has experience with qualitative research related to the nature of science. Upon developing and assigning codes, the researcher consulted his co-advisor and had a discussion with her about codes. Afterwards, the researcher revised the parts of analyses.

3.6.2 Analysis of Other Data

In this section, there is information about how interviews and reflection papers were analyzed and about their reliability.

3.6.2.1 Interviews

Interviews were transcribed and entered into NVivo qualitative data analysis software. Because all of the interviews were made in Turkish, these were translated into English by the researcher. Original Turkish texts and English version were presented in Appendix G. Accuracy of translations was reviewed by a Turkish Assistant Professor of Industrial Engineering at University of Missouri (Columbia, MO, USA). He completed his graduate work and has been living in the U.S. for the past 10 years. Therefore, he is fluent speaker of English. Using the same coding schema developed from the VNOS-B data, the researcher analyzed PSTs' responses.

Following this, codes assigned to interview and VNOS-B data for the same PSTs were compared to further establish the validity of the questionnaire data.

Interviews also included questions beyond simply identifying PSTs' views of NOS, and targeted PSTs' perceptions of the suitability of various activities to help them learn about NOS. New codes were created accordingly, and were categorized in such a way to highlight the strengths and weaknesses of the activities designed for use in the course.

3.6.2.1.1 Reliability of the Coding

Like the VNOS-B all of the process analyzing data, defining statements, deciding themes, and assigning codes were validated through extensive discussions the researcher did with the co-advisor. First, the researcher developed and assigned codes, and then, the expert checked and discussed, and then the researcher rearranged the parts of analyses.

3.6.2.2 Class Artifacts

PSTs wrote reflection papers at the end of the laboratory activities that included three open-ended questions, which were related to the laboratory topic and discussions. Each PST wrote seven reflection papers during the intervention. Reflection papers were word-processed and entered into the NVivo 8 qualitative data analysis software (QSR International, 2008).

New coding schema were developed from reflection papers, as a result of the researcher's analyses of the PSTs' responses. New schema includes the PSTs' reflections about definitions for each NOS aspect. Moreover, the inquiry skills, which are basic and integrated science process skills, are determined from reflection papers. In addition, the schema includes the roles of inquiry skills for understanding NOS aspects.

The three-stage data analysis technique used for VNOS-B pre and post data was also used for the analysis PSTs' reflection papers.

3.6.2.2.1 Reliability of the Coding

Like the other data, all of the process analyzing data, defining statements, deciding themes, and assigning codes were validated through extensive discussions the researcher did with the co-advisor. First, the researcher developed and assigned codes; next, the expert checked and discussed, and then, the researcher rearranged the parts of analyses.

3.7 Limitations of the Study

This study has some limitations. In this study, qualitative method was applied; therefore, the results of the study cannot be generalized. This study was conducted in the Laboratory Application in Science II course, and this course was limited in its special contexts; it did not include overall science contexts. Moreover, teaching time was limited to seven weeks (eight activities). Recent work by Akerson, Morrison, and Roth-McDuffie (2006) raises doubts as to whether changes in preservice teachers' understanding of NOS occurring over the course of a single-semester intervention are retained. In addition, during the intervention, many of the PSTs were enrolled in a method course, part of which related to understanding of NOS aspects, which might have interacted or influence preservice science teachers' understandings. Moreover, 45 preservice science teachers participated in the study, mostly females (34 female and 11 male). The PSTs were a fairly homogenous group, in that they were all of the same nationality, had the same science major background, and all of them were juniors. Further, according to Liu and Lederman (2007), teachers' NOS views are related to their worldviews, languages, and their cultures. This study was conducted in Turkey, our participants are Turkish PSTs, and therefore, their cultural characteristics might have affected the results of this study. Lastly, the present study focused on PSTs' own understanding about NOS concepts, not how to teach NOS. In the following section, there is information about the researcher's role, background, and his biases related to limitations of the study.

3.8 The Role of the Researcher

In qualitative research, the role of researcher is different and more complex than in quantitative research. Interactions between researchers and participants are important, and they should be made clear. This research aims to explore understandings of PSTs' NOS aspects during the explicit-reflective and inquiry-based laboratory instruction. Background, experiences, and views about NOS of the researcher may affect data collection procedures and interpreting results. For this reason, there is a need to gain more information about the researcher's backgrounds and NOS views.

The researcher holds a bachelor's degree in Elementary Science Education. He was a science teacher in public elementary school before starting his doctoral program. For the last several years, the researcher has attended to various projects, national and international conferences as a participant or educator. Before conducting the research, the researcher took some doctoral courses that included NOS and scientific inquiry. In addition, the researcher read recent dissertations (e.g., Deniz, 2007), books (e.g., Bell, 2008), reports (e.g., NRC, 2000), and articles (e.g., Abd-Abd-El-Khalick & Akerson, 2004; Schwartz, Lederman, & Crawford, 2004) in this area. The researcher's personal conceptions of scientific inquiry and NOS views were formed according to these sources. For this reason, the researcher thought that engaging in the explicit-reflective and inquiry-based instruction improves a learner's understandings of NOS views. During the data analyzing process, the researcher was aware of this bias. Another bias is related to NOS aspects, the researcher began the intervention with the empirical basis of NOS because he thought PSTs would be most familiar with the idea of evidence, versus other aspects such as the socio-cultural embeddedness of science. In the collecting data process, the researcher only conducted the interviews at the end of the semester. In addition, analyses all of the data were postponed until after the completion of the laboratory course to avoid biasing the collection of data.

On the first meeting of the laboratory course, the researcher gave a presentation and clarified the aims and procedures of the study. Then, he distributed consent forms; participants who agreed to join on voluntarily signed these forms. The consent form was presented in Appendix H. In this study, two sections were taught by teaching assistants, the researcher did not teach any section. However, in order to have deep information about PSTs' experiences, the researcher was in the laboratory sections throughout the semester. The researcher did not disturb any of the laboratory environments, due to the fact that the PSTs familiar with the researcher, who was one of the instructors in the previous semester's laboratory course.

3.9 Trustworthiness of the Study

In qualitative research, trustworthiness aims to favor results of the study that are "worth paying attention to" (Lincoln & Guba, 1985, p.290). There are four criteria to ensure the trustworthiness of any qualitative research; these are credibility, transferability, dependability, and confirmability (Guba & Lincoln, 1994).

The credibility issue matches with the internal validity in quantitative approach (Lincoln & Guba, 1985). This criterion is about an evolution of whether or not the results are credible. According to Lincoln and Guba (1985), the aim of credibility is to ensure "the match between the constructed realities of respondents (or stakeholders) and those realities as represented by the evaluator and attributed to various stakeholders" (p. 237). In this study to address credibility, three techniques were utilized, prolonged engagement, triangulation, and making explicit the researcher's bias (Lincoln & Guba, 1985).

Prolonged engagement with students includes the spending more time to obtain an understanding of a class or group (Guba & Lincoln, 1994). In this study, the researcher spent the whole semester with PSTs in order to build trust about the accuracy of data. In addition, before the study the researcher taught another laboratory course to the same PSTs during the previous semester. Therefore, the researcher had a chance to gain in-depth information about participants. Triangulation includes using multiple data collection methods to increase confidence in inquiry results (Lincoln & Guba, 1985). Triangulation was used in this research through using VNOS-B questionnaire, PSTs' reflection papers, and PSTs' interviews. Moreover, during the data analyses another researcher checked the coding process. In the role of the researcher part, there is information about the researcher's bias as a human who conducted this study. It can be stated that credibility was ensured for this study.

The transferability criterion was described as similar to generalizability or external validity in quantitative approach (Lincoln & Guba, 1985). The main idea in the transferability is to set up applicability of an inquiry' results to parallel settings; however, in qualitative research we cannot generalizations like quantitative research (Lincoln & Guba, 1985). The researchers emphasized the fact that "[t]ransferability is always relative and depends entirely on the degree to which salient conditions overlap or match" (Guba & Lincoln, 1989, p. 241). In the present study, transferability was achieved by thoroughly detailed descriptions of the research process and methodology. For this reason, a reader can easily understand the methodology and laboratory settings. Although the researcher did not aim to generalize the results to all laboratory courses and PSTs, the results of the current study may be transferable to research with similar methodology.

The dependability criterion matches with the consistency and reliability in quantitative approach (Lincoln & Guba, 1985). Replication is not possible for qualitative research because it is directly related to nature of human. However, the researcher can provide dependability by using consistent themes across many sources of data. In the present study, the researcher used triangulation of data in the form of the questionnaire, PSTs' reflection papers, and PSTs' interviews in order to ensure dependability.

In accordance with Guba and Lincoln (1994), ensuring confirmability corresponds to maintaining objectivity in quantitative approach. Confirmability criterion includes assessment of the data to be sure that the data presented is truthful. In the current study, the researcher gave many quotations from the raw data in order to support the researcher's interpretations and conclusions. Moreover, another researcher checked the researcher's interpretations from the raw data to ensure confirmability. Furthermore, the researcher was aware of his perceptions and beliefs might lead his interpretations.

CHAPTER 4

FINDINGS

This chapter includes findings generated from data analysis. In this part, all of the data were analyzed and summarized.

4.1. Research Question 1

In this section, the first research question and sub-questions were analyzed. Therefore, the connections between laboratory activities and the targeted NOS aspects were described. Next, changes in PSTs' views of NOS were examined, both in aggregate terms as well as by examining changes in individual PSTs' understanding. Then, the connections PSTs made among various aspects of NOS were analyzed.

4.1.1 Connection between NOS Aspects and Inquiry-Based Laboratory Activities

In order to understand how each specific laboratory activity affected PSTs' views of NOS, the ideas were identified from data. These ideas about NOS those PSTs in the course related to each of the explicit and reflective activities. This was accomplished by cross-referencing data coded for each aspect of NOS as well as for each of the activities (e.g., explicit responses to the activities in post-semester VNOS, interviews, and reflection papers written at the end of each activity). The emphasized relationship between NOS aspects and characteristics of each laboratory activity are presented in the next section.

4.1.1.1 Empirical Basis of NOS

The first two activities were related to understanding of the empirical basis for scientific knowledge. For the first activity, "Germination of a Seed" (developed by the researcher), the PSTs tried to find which variables may affect the rate of germination. For the second activity, “Photosynthesis” (adapted from, Baruch, 2008), the participants formed groups and designed investigations to determine which variables may affect the rate of photosynthesis.

Specifically, the goal of these activities was achieving an understanding of the way that scientific knowledge is based on evidence and observations of the natural world (Abd-El-Khalick & Akerson, 2004; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Schwartz, Lederman & Crawford, 2004). This aspect of NOS can be seen as a distinguishing feature of science as a way of knowing. After completing these laboratory activities, all of the PSTs (100 %) expressed ideas, which were consistent with our expectation. For example, many (35) of the PSTs recognized that knowledge in science relies on evidence, rather than authority. Below some excerpts are given as the representative of this idea.

> PST #28 (Preservice science teacher number 28 from reflection paper): Scientific knowledge is not dogmatic because while producing scientific knowledge we make observations, experiment, collect data and by using these we made our interpretations and produce scientific knowledge. In the experiment of photosynthesis, we saw the empirical basis of NOS. We are all taught that photosynthesis requires CO_2 and light input and we get starch after photosynthesis. By removing them one by one, we saw the effects of CO_2, no starch produced, so we understand that CO_2 is required for photosynthesis, now we are not just told that CO_2 is required, we also observed that CO_2 is required.

> PST #1 from reflection paper: Scientific knowledge must be rational. It means it can be tested in laboratories. By doing many experiments we observe how we make sure about the related scientific knowledge. In this week, we directly made an experiment and directly observed the things affecting photosynthesis. By this way, we gained evidence in ourselves and observed empirical basis.

> PST #13 from reflection paper: Empirical nature of science knowledge means that we should have evidence for support the hypothesis or theory. We cannot prove our hypothesis with imaginary ideas. We should have data and their consequences. In this week, we try to describe the requirements of photosynthesis. In order to support our hypothesis, we follow a procedure whether CO_2 or light is needed or not. After our observation of the changes, we conclude that CO_2 and light is necessary for photosynthesis.

Generally, the PSTs claimed that there should be some processes to reach scientific knowledge. During these processes we can test our hypotheses and we can reach scientific knowledge, these knowledge are rational not dogmatic. Moreover, the PSTs emphasized that to generate scientific knowledge we need data and evidence, which can be obtained by doing experiments and observations.

In addition, some (14) other PSTs focused on cause-effect relationships and the importance of experiments for the reliability of generated scientific knowledge. The PSTS highlighted the importance of experiments. They stated that doing experiments can promote showing cause-effect relationships for scientific knowledge. Moreover, they focused scientific knowledge should be reliable, and to support reliability we need experiments. Below, an excerpt is given as the representative of this idea.

> PST #16 from interview: Certainly, experiments are important in science, because reaching scientific knowledge is difficult without experimentation. In order to show the reality of something we need to show cause effect relationships, thus, we need experiments. Experiments are the first step for scientific knowledge. Results of experiments are not different according to people, thus this support reliability for knowledge.

It can be concluded that after completing the two laboratory activities, all of the PSTs connected these activities to the targeted NOS aspect, which scientific knowledge is based on evidence and observations of the natural world.

4.1.1.2 Observation & Inference

The second activity (Black Box, adapted from Lederman & Abd-El-Khalick, 1998) was related to the importance of observation and inference for scientific knowledge and differences between them. Specifically, the researcher intended PSTs to understand that scientific knowledge includes observation and inference. They are different in that observations are gathered through human senses and inferences are interpretations of those observations (Abd-El-Khalick & Akerson, 2004; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Schwartz, Lederman & Crawford, 2004). In the "Black Box" activity, PSTs observed a black box into which an amount of water was poured, and double that amount exited the box. PSTs developed models to represent what they believed was inside of the Black Box.

All of the participants (100 %) stated ideas consistent with our intent. They showed their understandings about observations and inferences. The (28) PSTs expressed that observation and inference are different, and both of them are important for scientific knowledge. Below there are some excerpts, which represent of this idea.

> PST #35 from interview: In the laboratory, we observed directly the box; we stated our observation without interpretations. For inference, we tried to discovery a system inside the box. In the laboratory, our observations were same but our inferences were different.

> PST #29 from reflection paper: Science is based on observation, then after making observation scientists make some inferences according to their observation. The inferences [that scientists draw] can be different from each other. In this week, we observed about black box. We put 150ml of water into the box and we got 350ml of water. Next, we made inferences that there should be some of water in the black box, and according to our inferences, we setup an experiment which supported our observation. The experiments designed by all groups were different from each other because of different inferences.

> PST #32 from reflection paper: The aspect of NOS related to scientific knowledge includes observation and inferences, and these two are different. Observations include our five senses and contain static and dynamic conditions. Inferences are different; they are made or designed according to our observations. In this week, we observed the black box; 150ml water poured and got 350ml of water. Then, we made some inferences about inside the box. Every group had different inferences, although our observation was same.

These PSTs emphasized the differences between observation and inferences. They stated that even though all groups had similar observations, they had different inferences which resulted in having different designs for the inside the box.

Many (17) of the PSTs stated the relations between inferences and scientific models, which scientists develop to explain for natural phenomena. Below, there are some excerpts, which represent of this idea.

> PST #32 from interview: Especially, for some science topics we have to infer, for example, about atom, about universe, and evolution we cannot do experiments. By means of inferences, we formed models to explain some topics. In the laboratory we observed the box, we could not see inside, thus we made some inferences about its system, I think this was important.

> PST #24 from reflection paper: Scientific knowledge includes inference, for example; we do not know the atom structure absolutely but scientists make inferences related to that subject and with some observations, they come up with some theories about the situation.

> PST #13 from interview: In laboratory, we did not see inside the box, we did inferences. I understand scientists made some inferences about unobservable things and they reach scientific knowledge. We observed same thing but we had different designs.

These PSTs held the view that science is a way of understanding the world, but some of the areas there is no way to design an experimental setup. Therefore, scientists' use their inferences and they try to understand some phenomena, which cannot be seen by naked eye.

It can be stated that after completing the Black Box activity, all of the PSTs connected the activity to the targeted NOS aspect, which scientific knowledge includes observation and inference, and they are different.

4.1.1.3 Theory & Law

The third activity was related to understandings of theories and laws. Specifically, the researcher provided an environment for PSTs to understand that theories and laws are different kinds of scientific knowledge and one does not become the other. Laws describe relationships, observed or perceived of phenomena in nature. On the other hand, theories are inferred explanations for natural phenomena and mechanisms for relationships among natural phenomena (Abd-el-Khalick & Akerson, 2004; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Schwartz, Lederman & Crawford, 2004). The PSTs completed an activity name was "Boyle-Mariotte and Gravity Laws" (develop by the researcher). To complete this activity every group chose one law and related theory. Then all groups formed different experimental designs based on these laws and theories they selected.

According to pre-semester VNOS-B, some (12) of the PSTs showed a common misunderstanding that there are hierarchical steps among hypothesis, theories, and laws. However, they remedied their misconceptions after the activity. For example;

> PST #38 from interview; Before this activity I thought that theories become laws and laws cannot change, because this knowledge was taught us, every person in the laboratory had these wrong conceptions. In the science books, there were graphics [show vertical relationships among hypothesis to law], thus we learned wrongly.

After the activity, many of the PSTs (91,2 %) expressed ideas consistent with the researcher intent. Generally, the PSTs understood differences between theory and law, and their importance for scientific knowledge. For example, a PST stressed that:

> PST #10 from interview: In this laboratory, we used Boyle-Mariotte law, and we designed an activity, to explain relationship between pressure and volume we used molecular kinetic theory. Theories try to explain laws.

Many (31) other PSTs mentioned about differences between theory and law, and theories try to explain laws. Below, there are two excerpts, which represent of this idea.

> PST #18 from reflection paper: Laws and theories are different, laws are observable phenomena, but theories try to explain laws by using experimental knowledge. In our experiment, we designed an experiment; it shows us the relation between the pressure of gases and the volume of gases. When we decreased the volume of gases, pressure of gases increased. Molecular kinetic theory explains this phenomenon with collision of gas's molecules increase and pressure of gas will increase due to decreasing of volume.

> PST #13 from reflection paper: In this week, we made experiment about Boyle-Mariotte's law. When the pressure of a gas is increased, the volume of the gas decreases at a constant temperature. The molecular kinetic theory explains the law. The theory; when we increase the temperature of a gas, the molecules' movement of the gas will increase, and then the pressure of the gas increases. Kinetic theory answer the question of the Boyle's law which is why do the pressure of gas increase?

In these statements, the PSTs stressed their understanding about the differences between theories and laws.

In our cross-referencing, we did not find explicit connections between the activity and this aspect of NOS for four PSTs (PST #36, PST #40, PST #43, and PST #44). Although, they did not directly mention about the "Boyle-Mariotte and Gravity Laws" activity, they provided statements about differences between theories and laws after the activity. For example:

> PST #40 from reflection paper: Theories and laws are different. Theories are explanations for laws. Theories never turn into laws.

> PST #43 from reflection paper: Laws are observable definitions of the natural phenomena in nature. They are answer of the questions "what" and "how." Theories try to answer of "why" questions.

These statements showed that the PSTs understood the difference between theories and laws, and their importance for scientific knowledge. Why they did not link the targeted NOS aspect and the activity? This question can be explained like, as during the data collection procedure, the PSTs were not confronted with a question like; is there any connection or relationship between this (any) NOS aspect and this (any) laboratory activity? For this reason, they might not link this NOS aspect and the activity.

4.1.1.4 Subjectivity

The fourth activity was related to understanding of subjectivity. In this activity, PSTs had the same DNA strands for human, gorillas, chimpanzees, and apes. Some groups were assigned a ladder evolution theory, some others were assigned a common ancestor evolution theory by instructors. Specifically, the researcher indented PSTs to understand theoretical subjectivity, we mainly focused effects existing theories on effects on scientific knowledge. The theory-laden nature of scientific knowledge means that scientific knowledge is theory-laden, scientists' theoretical and disciplinary commitments influence their works (Abd-El-Khalick & Akerson, 2004; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Schwartz, Lederman & Crawford, 2004). The activity name was "Evolution Theories!" (adapted from NAS, 1998), in this activity participants had the same data but two different theories about evolution, and PSTs reached different conclusions at the end of the activity.

All of the PSTs (100 %) expressed ideas consistent with our intent. They realized that existing theories can affect scientists' studies and they gave examples from the laboratory activity. Below, three excerpts are given as the representative of this idea.

> PST #1 from interview: I think scientists are affected [by their] existing theories while conducting research. In the laboratory, we formulated some hypotheses according to our theory. Different groups had different hypotheses because of the different theories. At the end, every group reached different results from the same data, but all of the results were acceptable.

> PST #15 from interview: In laboratory, we were given DNA strands, there were two different theories about evolution. We had same data but at the end, we supported different hypotheses. I understand that scientific knowledge is affected from existed theories. Theories can guide research. In this activity, we formulated our hypothesis according to our theory.

> PST #21 from interview: I think during scientific investigation scientists are affected existed theories normally. In this activity, we used same data but we had different theories, our conclusions were different. Our expectations were affected from our theories. Scientists can reach different results from same data. I understood science is subjective, not objective. Especially, there are some subjects are very controversial, for example evolution.

The PSTs understood the effects of existing theories on scientific investigations. They gave examples from their laboratory experiences. They asserted scientists could reach different results from same data because of different theories.

Many (34) of the PSTs mentioned about subjectivity, that is directly related to scientists' choose for theories. They focused on scientists' personal references, as an important factor should affect scientific studies. Below there are two excerpts, which represent of this idea.

> PST #27 from interview: In the laboratory, we supported different theories using same data. I understand scientists can use scientific data according to their target or something they want to support. I think this related to

subjectivity in science. Scientists use previous theories to analyze present data. If there are some different theories about a topic, scientists can select one of them according to their previous knowledge or their beliefs. For example, some scientists support evolution theory for origin of species, some others can support creationism. This is controversial topic, and I think scientists are not objective.

PST #24 from reflection paper: This week, we were given two different theories related to evolution. Then we used the same data, used the same model by following the same steps and formulated hypotheses. After, we all supported our hypothesis although they are different. This shows that, we are influenced from the theories that we used. Scientists also do same thing so we can say science is subjective.

In these statements, the PSTs emphasized the relationships between subjectivity in science and the role of theories, which are preferred by scientists. They mentioned their references in the activity and effectiveness of theories for guiding their investigations. In addition, they concluded that scientists are affected theories during scientific research, this cause subjectivity in science.

Some (16) of the PSTs stressed that before scientific studies scientists choose theories, in this process there are some other factors may affect scientists' preferences. For example, their background knowledge, their culture, and their expectations may affect process of choosing theories. Below, there are two excerpts, which represent of this idea.

PST #23 from interview: I understand different scientists can be affected different theories according to their culture and their previous knowledge. For example, there are different theories about extinction of dinosaurs.

PST #1 from reflection paper: In this week we designed an experiment, we observed that there was the same data [same DNA strands], the groups in the laboratory section developed different hypothesis and reached different results. Because ever group used their prior knowledge, theories, expectations, creativity etc, so all these make the ideas were different.

In these statements, the PSTs focused on some individual factors and some personal differences for scientists, they can affect scientists' studies.

4.1.1.5 Tentativeness

The fifth activity was related to tentativeness of scientific knowledge. Specifically, we aimed PSTs to understand the tentative nature of scientific knowledge, it means that scientific knowledge is never absolute or certain, scientific knowledge is subject to change with new observations and with the reinterpretations of existing new knowledge (Abd-El-Khalick & Akerson, 2004; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Schwartz, Lederman & Crawford, 2004). The activity name was "Age of Fossils" (developed by the researchers); to complete this activity every PST was given some fossil fragments, and according to given information PSTs tried to decide the fossils fragments' ages.

All of the PSTs (100 %) expressed ideas consistent with our aim. Many (21) of them declared similar situations in which scientific knowledge is subject to change. Below, there are three excerpts, which represent of this idea.

> PST #11 from interview: In the past scientific knowledge changed, thus scientific knowledge can change. In laboratory, we ordered fossils we used our knowledge and our creativity, after new knowledge came we changed our sorting. However, this characteristic does not mean science is unimportant, today we use scientific knowledge, which can be changed in future.

> PST #26 from reflection paper: In this week, we designed an experiment related to the age of fossils. Firstly, we classified the fossil fragments according to some criteria in our mind. Then, with the new information, we classified the fossils fragment in order to see which one is older. The sequence changed with new information, this means that scientific knowledge is tentative.

PST #40 from interview: Scientific knowledge can be changed in time. New knowledge can change existing knowledge. I understand that, scientific knowledge is not absolute and not stable it is subject to change. In the laboratory, we observed fossils and ordered, then new knowledge came we changed our order.

The PSTs focused on tentative nature of scientific knowledge. New interpretations and new scientific knowledge can change existing knowledge. In addition, the PSTs emphasized that there is no certain or absolute knowledge in science. In the activity, the PSTs realized they changed fossils' order in light of new scientific knowledge.

Some (17) PSTs stressed the relationship between of tentative NOS and development of science. According to these students science can develop because of its' tentative nature otherwise it will stay same for years. Below, there are three excerpts, which represent of this idea.

PST #7 from interview: Scientific knowledge is changeable, but this is not deficiency for science. Science does not include absolute scientific knowledge, thus new information can change existed knowledge, and this develops science.

PST #3 from interview: I think science change continuously. It changes slowly but it changes. In the past people made something, they were changed today, tomorrow our scientific knowledge will be changed, and thus science will be developed. Everything is changeable.

PST #4 from interview: I believe that scientific knowledge should be change, because its changing causes its development. If we accept that scientific knowledge does not change, anybody try to develop it. However, if we accept it can be changed, people try to find new things and investigate continuously. Moreover, science related to nature and nature changes continuously, thus science should change, this causes development.

The PSTs focused on the role of tentativeness to develop scientific knowledge. This is important because participant understood the main idea under the tentativeness.

Tentativeness is not meaning that failure of scientific knowledge, it promotes development of science.

4.1.1.6 Creativity & Imagination

The sixth activity was related to understanding the role of creativity and imagination for scientific knowledge. In this activity, a fossil fragment was given to every PST, and they were expected draw some lost parts and its environment lived in the past. Specifically, we aimed PSTs to understand the creative and imaginative nature of scientific knowledge. It means that scientific knowledge is created from human imaginations and logical reasoning, this creation is based on observations and inferences of the natural world (Abd-El-Khalick & Akerson, 2004; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Schwartz, Lederman & Crawford, 2004). The activity name was "Real Fossils" (adapted from Bell, 2008), in this activity each group was provided different fossil fragments, and was asked to draw what they believed the entire fossil looked like.

Approximately, all of the PSTs (97, 8 %) (except that PST #23) expressed ideas consistent with our intent. PST #23 did not write reflection paper, and s/he did not answer during the interview about this activity. Generally, (38) PSTs stressed the importance of creativity and imagination for scientific knowledge. Below, there are some quotations, which represent of this idea.

> PST #28 from interview: In laboratory, we draw different creatures from the same fossils' fragments. I understand science is affected from scientists' creativity and imagination. I think some theories are product of creativity; for example, relativistic theory.

PST #43 from interview: We draw different creatures from same fossils. Because of our creativities and imaginations were different. I think scientists are affected from their creativities and imagination, because their human beings like us.

PST# 13 from interview: I think scientists' creativity and imagination affect scientific knowledge. In the laboratory, some friends and I had same fossil, but we drew differently according to our imagination and creativity. When I saw my friends' different drawings, I was shocked. They were very different.

PST #5 from interview: In laboratory class we had same fossil fragments, but every people drawn differently fossils' remaining parts. Because of, every people had different imagination. Thus, imagination and creativity affected our drawings. We saw that in science scientists' imagination affect their works.

PST #24 from reflection paper: Scientific knowledge has a creative and imaginative nature. All people and scientists have different logical thinking, background and also different imagination and creativity. This week, we conducted an experiment, there are different people have the same picture. Therefore, every person defined differently given fragment because of different creativity and imagination. We can say that, scientific knowledge is constructed from human imaginations and creativity.

PST #36 from reflection paper: Creativity and imagination affect observations and inferences. By creativity and imagination, scientists get a conclusion but because they have different creativity and imagination, they get different conclusion from others. In this experiment, we have same fossils fragments but because of our creativity and imagination we get different conclusion.

In these statements the PSTs exampled from the laboratory activity and they realized that creativity and imagination affect scientific knowledge. In addition, they mentioned that different people has different creativity and imagination.

Although it is similar with creativity and imagination impact on science, some (15) PSTs especially emphasized especially scientist use their creativity and imagination during their scientific investigations. Below, there are three quotations, which represent of this idea.

PST #40 from reflection paper: The aspect of NOS focused that scientific knowledge is based on human's imagination and creativity. Scientists use their imagination and creativity to complete scientific works. Today while doing our experiment, we used fossil fragments and we tried to infer what can be arisen from these fossil fragments.

PST #11 from reflection paper: According to the NOS aspect, scientific knowledge is a product of creativity and imaginations of scientists. Scientists use their observations and make inferences about the world. Using creativity and imaginations scientific knowledge occurs in a logical way.

PST #12 from reflection paper: Scientists create scientific knowledge by using their own imagination and creativity. They observe same thing but they inference differently from each other. Their creativity and imaginations influence their studies.

The PSTs understood the importance of creativity and imagination, because they focused on scientists, who develop scientific knowledge. Other people can use their creativity and imagination. However, scientists directly affect development of scientific knowledge, therefore, this is an important characteristic of scientific knowledge.

4.1.1.7 Socio-Cultural Effect

The seventh activity was related to understanding the impact of social and cultural factors on scientific knowledge. In this activity, PSTs designed different experiments using water according to their different needs. Specifically, we aimed PSTs to understand the social and cultural embeddedness of scientific knowledge. It means that science affects and is affected by the various elements and intellectual spheres of the culture in which it is embedded, these elements include, but are not limited to, social fabric, power structures, politics, socioeconomic factors, philosophy, and religion (Abd-El-Khalick & Akerson, 2004; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Schwartz, Lederman & Crawford, 2004). The activity name was "Which Water!" (developed by the researcher), for this activity the PSTs formed groups and were asked to role play groups in society with different needs. Each group then setup an investigation to explore different properties of water related to their needs.

Approximately, all of the PSTs (97, 8 %) (except that PST #23) expressed ideas consistent with our intent. PST # 23 did not write reflection paper, and s/he did not answer during the interview about this activity. Generally, PSTs realized that social factors affect development of scientific knowledge. Below, there are three quotations, which represent of this idea.

> PST #33 from interview: In the laboratory, we represented different society, and we need different things and we had only salty water. Our society need drinking water and we did distillation and we reached drinkable water. Our needs guide our study.

> PST #21 from reflection paper: This week, we had given three different cases. Each was about different situations and cultures with different needs. The common thing in these cases was water. Three different cultures, which had enough water, need different things. For example, we need H gases. Therefore, we tried to obtain H gas from water with electrolyze. Other groups used water for different purposes. This showed us science develops according to needs of society.

> PST #12 from reflection paper: Today we made experiment related to this aspect. There are different groups (societies) in the laboratory we used same water, but needs were different, some groups need distilled water to drink, some need H and O gases etc. because people live in different environment, society, culture, who has different religion, politics, they have different need and purpose. This shows that scientific knowledge is socially culturally embedded.

It can be understood from these statements the PSTs realized that society and culture could affect science. The PSTs exampled their laboratory experiences, they had different needs and they designed different systems. This is similar historical development of science. Science is constructed by scientists in society, and we cannot separate from science and society from each other.

4.1.1.8 Summary

Generally, all of the PSTs were able to make appropriate connections between the laboratory activities and the targeted aspects of NOS. Even though I focused on one particular aspect of NOS in each activity, there were certainly other aspects of NOS reflected in these activities. However, sometimes the connections the PSTs made were not appropriate; that is, they reflected students' misconceptions about NOS. However, I anticipated that by the end of the semester, such ideas would change. To determine this, I examined the PSTs' views of NOS pre- and post-semester to identify whether and how their views of NOS changed. In the next section, I present findings related to changes in PSTs' views of NOS according to each of the aspects of NOS targeted in the intervention.

4.1.2.1 Changes in Preservice Science Teachers' Views of NOS; Aggregate Findings

The preservice science teachers' responses to the pre and post VNOS-B were word-processed and entered into the NVivo 8 qualitative data analysis software (QSR International, 2008). As I mentioned in the method section a three-stage data analysis technique was devised, the unit of analysis was a statement. All of the statements were coded according to Lederman, Abd-El-Khalick, Bell and Schwartz, (2002) and Hanuscin (2009). According to Lederman et al. (2002), inconsistent coding statements are naïve views. As for the transitional coding statements, they include some but not all informed views. However, consistent coding statements are suitable views according to recent reforms. Appendix F represents these inconsistent, transitional, and consistent views. Table 4.1 represents PSTs' views of NOS aspects from pre and post VNOS-B results. Informed NOS views represent adequate understandings of NOS aspects. In this table, PSTs' statements about NOS views were classified according to current science reforms. According to the pre-VNOS-B results, PSTs initially had some contemporary views for at least one of the NOS aspects. These percentages are between 27% (for Socio-Cultural Effect) and 46, 80% (for Empirical NOS). However, according to the post-VNOS-B results the PSTs' informed views about NOS aspects were developed. These developments are between 6, 40% (for Empirical NOS) and 46% (for Socio-Cultural Effect) percentages. It means that the number of statements that were aligned with contemporary views of NOS increased in the post VNOS-B data. The percentages for all of the NOS aspects can be seen below Table 4.1. This table represents 34 PSTs' statements, because 11 PSTs (7 pre; 4 post) did not complete the VNOS-B in the laboratory. Therefore it could not be compared these PSTs' pre and post VNOS-B results.

Table 4.1. Informed statements about NOS aspects from pre and post VNOS-B

	Empirical NOS		Observation & Inference		Theories & Laws		Subjectivity		Tentativeness		Creativity		Socio-Cultural Effect	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Total scores*	103	117	70	101	55	121	72	107	67	100	89	137	10	27
Percentages**	46,80%	53,20%	40,90%	59,10%	31,20%	68,80%	40,20%	59,80%	40,10%	59,90%	39,30%	60,70%	27%	73%
Change		+6,40%		+18,20%		+37,60%		+19,60%		+19,80%		+21,40%		+46%

*Total scores refer to number of statements, which participants stated in their VNOS-B pre and post application. These statements are informed NOS views with current reforms.

**According to the number of statements the percentages were calculated.

In this section, each of the NOS aspect will be investigated depth according to PSTs' statements for pre and post VNOS-B results. For every NOS aspect and its subcategories, a table was created. These tables show numbers and percentages for PSTs, who completed pre and post VNOS-B. According to VNOS-B results 37 PSTs joined pre application and 41 PSTs attended post application. Therefore, comparisons were constructed between pre and post results for these PSTs.

4.1.2.1.1. Empirical Basis of NOS

In order to perceive changing of PSTs' understanding of Empirical Basis and its subcategories the Table 4.2 was constructed. There are five categories under specific empirical basis of NOS aspect. In four categories according to post-test results PSTs' numbers and percentages were increased in respect of their pre application. The last category is "Scientific knowledge is objective" not informed views of empirical basis of NOS. There were decreases for PSTs' numbers and percentages according to their pre application. Below, there are some quotations, which represent of this subcategory.

> Part #14 from pre-VNOS-B: In science, absolute and unchangeable findings can be reached.
>
> PST #33 from pre-VNOS-B: Scientific knowledge is absolutely true.
>
> PST #32 from pre-VNOS-B: Science should be objective in order not to make mistakes.

Total 8 (21, 62%) participants declared similar statements about objectivity of scientific knowledge, however this number decreased 2 (4, 87%) at post-test. These two PSTs stated that;

PST #13 from post-VNOS-B: Yes, scientific knowledge can be certain.

PST #38 from post-VNOS-B: Scientific knowledge is more objective.

It can be seen from the Table 4.2 all of the subcategories about empirical basis of NOS the PSTs showed improvements for their understandings.

Table 4.2. Prevalent views about Empirical Basis of NOS from pre and post VNOS-B

	Pre-test (37)	Post-test (41)
	Number (%)	Number (%)
Scientific knowledge is empirical based	28 (75,67 %)	35 (85,36 %)
Scientific knowledge requires empirical evidence	15 (40,54 %)	14 (34,24 %)
Observation important for scientific knowledge	3 (8,10 %)	5 (12,19 %)
Personal opinions are subjective	28 (75,67 %)	37 (90,34 %)
Scientific knowledge is objective	8 (21,62 %)	2 (4,87 %)

4.1.2.1.2 Observation and Inference

The Table 4.3 was formed to identity changing of PSTs' understanding of observation-inference and its subcategories. It included five subcategories, these are, Observation for experimental evidences; Inference for models in science; Observation and inference are different; Scientific knowledge is inferred; and Scientific knowledge is observed. According to Table 4.3, all of the subcategories about observation and inference the PSTs developed their understanding.

Table 4.3. Prevalent NOS views about Observation and Inference from pre and post VNOS-B

	Pre-test (37)	Post-test (41)
	Number (%)	Number (%)
Observation for experimental evidences	2 (5,40 %)	5 (12,19 %)
Inference for models in science	8 (21,62 %)	17 (41,46 %)
Observation and inference are different	4 (10,81 %)	8 (19,51 %)
Scientific knowledge is inferred	21 (56,75 %)	28 (68,29 %)
Scientific knowledge is observed	15 (40,54 %)	10 (24,39 %)

Post VNOS-B results showed that the PSTs' numbers and percentages were increased in respect of their pre application for first four categories. The last category is "Scientific knowledge is observed" not informed views about observation and inference. There were decreases numbers of participants and percentages according to their pre-test results. Total 15 (40, 54%) PSTs mentioned about observing of scientific knowledge, they were related to structure of atom. For example;

> PST #22 from pre VNOS-B: It (atom) can be seen using electron microscope.
>
> PST #7 from pre VNOS-B: It (atom) looks like a core and an electron cloud around it by the help of the electron microscope. They (scientists) use some experiments like glucose oil drop experiment.

However, this number decreased 10 (24, 39%) at post-test. One of the participants stated that:

PST #6 from post-VNOS-B: Scientists look at atom with electron microscopes.

4.1.2.1.3 Theory and Law

In order to show changing of PSTs' views about theory and law the Table 4.4 was designed by using their pre and post VNOS-B scores. This table integrated four subcategories under theory and law. These are; Theories do not become laws; Theories explain laws; Laws cannot change; and Theories can change. This table illustrates that for all of the subcategories PSTs developed their understandings according to their pre application results.

Table 4.4. Prevalent NOS views about Theory and Law from pre and post VNOS-B

	Pre-test (37)	Post-test (41)
	Number (%)	Number (%)
Theories do not become laws	0 (0 %)	12 (29,36 %)
Theories explain laws	4 (10,81 %)	31 (75,60 %)
Laws cannot change	27 (72,97 %)	5 (12,19 %)
Theories can change	18 (48,64 %)	38 (92,68 %)

According to post VNOS-B results some PSTs stated that there is no hierarchical relationship between theories and laws and they are different kinds of scientific knowledge. Although, there is nobody mentioned at pre application, total 12 (29, 36%) PSTs gave statements at post application. Below there are some quotations, which represent of this subcategory.

> PST #4 from post VNOS-B: Theories never can turn to laws.
>
> PST #31 from post VNOS-B: Theory and law are different and they do not become other one.
>
> PST #12 from post VNOS-B: They cannot translate into another.

In addition, this table showed that the PSTs' numbers and percentages were decreased in respect of their pre application for one subcategory; Laws cannot change. While the numbers and percentages of participants were 27 (72, 97%) in the pre-test, at the end of the course these decreased to 5 (12, 19%). For example:

> PST #10 from pre VNOS-B: "… while whether or not the evolution theory is true is still being discussed, Newton's laws cannot be changed. That is law cannot change."

> PST #14 from pre VNOS-B: "…, laws do not change, that is laws are absolutely proven."

> PST #20 from pre VNOS-B: Laws are accepted universally and they cannot be changed.

4.1.2.1.4 Subjectivity

In order to detect the effectiveness of intervention about subjectivity of scientific knowledge the Table 4.5 was designed according to answers of PSTs' pre and post VNOS-B applications. This table includes four subcategories, which are related to reasons for subjectivity of scientific knowledge. These are; Creativity and imagination; Educational background; Personal references; and Using existing theories. There is another subcategory related to this aspect, it is "Scientific knowledge is objective." It can be found more explanation about this category in the earlier Observation and Inference aspect. According to Table 4.5, PSTs realized importance of all of the subcategories and they showed their understandings of NOS aspect.

Table 4.5. Prevalent views about Subjectivity of NOS from pre and post VNOS-B

	Pre-test (37)	Post-test (41)
	Number (%)	Number (%)
Creativity and imagination cause subjectivity	2 (5,40 %)	9 (21,95 %)
Educational background cause subjectivity	5 (13,52 %)	16 (39 %)
Personal references cause subjectivity	30 (81 %)	34 (82,92 %)
Using existing theories cause subjectivity	6 (16,21 %)	21 (51,21 %)

In Table 4.5, the most striking changing in subcategories is detected as using existing theories. According to their pre-test result only 6 (16, 21%) PSTs mentioned about using existing theories, however, after the intervention 21 (51, 21%) PSTs focused the importance of existing theories for subjectivity of scientific knowledge. For example,

> PST #36 from post VNOS-B: Scientific knowledge is theory-laden, scientists use previous theories and develop new theories.

> PST #8 from post VNOS-B: Scientists can fallow different theories, thus they can claim different opinions, and they can make different conclusions.

> PST #29 from post VNOS-B: Science is theory-laden, scientists can do new research, experiments based on previous theories.

4.1.2.1.5 Tentativeness

Tentativeness is one of the most important characteristics of scientific knowledge. In order to determine the development of PSTs' understandings about tentativeness of scientific knowledge Table 4.6 was constructed. This table shows numbers and percentages for PSTs, who completed pre and post VNOS-B. Table 4.6

includes two subcategories, which are related to tentativeness of scientific knowledge. These are; Technology and new evidences can change scientific knowledge; and Tentativeness promotes scientific development.

Table 4.6. Prevalent views about Tentativeness of NOS from pre and post VNOS- B

	Pre-test (37)	Post-test (41)
	Number (%)	Number (%)
Technology & New evidences can change knowledge	7 (18,91 %)	21 (51,21 %)
Tentativeness promotes scientific development	3 (8,10 %)	17 (41,46 %)
Truth of scientific knowledge	11 (29,72%)	2 (4,87%)

According to Table 4.6, PSTs have major developments for two subcategories. While the numbers and percentages of PSTs were 7 (18, 91%) in the pre-test, at the end of the course these increased to 21 (51, 21%) for “Technology and new evidences can change scientific knowledge”. For example:

> PST #6 from post VNOS-B: Theories can be changed with respect to time, new explanations, new information, and new findings.

> PST #15 from post VNOS-B: Scientific knowledge is tentative. If we have new evidence, scientific knowledge can be changed.

Similarly, PSTs realized that the characteristic of tentativeness promotes development of scientific knowledge. Only 3 (8, 10%) PSTs mentioned about this subcategory at the pre-test, however, 17 (41, 46%) PSTs stated at post-test results. These numbers and percentages show developments of understanding tentativeness of NOS. For example:

> PST #4 from post VNOS-B: Theories can change, science should be developed by these changing.

PST #10 from post VNOS-B: Theories can be changed, these changes cause the development of science.

According to Table 4.6 PSTs changed their understanding about truth for scientific knowledge after the intervention. While the numbers and percentages of PSTs were 11 (29, 72%) in the pre-test, at the end of the course these decreased to 2 (4, 87%). Below there are some quotations, which represent of this subcategory.

PST #13 from pre VNOS-B: Scientific knowledge is the truth of the opinions.

PST #14 from pre VNOS-B: Scientific knowledge is mostly true.

PST #18 from pre VNOS-B: A theory is accepted true, if there is not any theory, which eliminates it.

PST #33 from pre VNOS-B: Scientific knowledge is absolutely true.

4.1.2.1.6 Creativity and Imagination

Table 4.7 was constructed to show changing of PSTs' understanding of creativity-imagination and its subcategories. It included five subcategories. These are; Science and art different; Science and art similar; Scientists do not use creativity and imagination; Scientists partially use creativity and imagination; and Scientists use creativity and imagination. Table 4.7 demonstrates that for all of the subcategories participants developed their understandings according to their pre-VNOS-B results.

Table 4.7. Prevalent views about Creativity and Imagination of NOS from pre and post VNOS-B

	Pre-test (37)	Post-test (41)
	Number (%)	Number (%)
Science and art different	29 (78,37 %)	20 (48,78 %)
Science and art similar	20 (54 %)	36 (87,80 %)
Scientists do not use creativity and imagination	5 (13,52 %)	0 (0 %)
Scientists partially use creativity and imagination	10 (27 %)	5 (12,19 %)
Scientists use creativity and imagination	20 (54 %)	38 (92,60 %)

According to Table 4.7, PSTs have most important developments for three subcategories, which are accepted as misconceptions. Firstly, while the numbers and percentages of PSTs were 29 (78, 37%) in the pre-test, at the end of the course these decreased to 20 (48, 78%) for "Science and art different." Below there are some quotations, which represent of this subcategory.

> PST #12 from pre VNOS-B: Science reaches its goals by experiments, observations, and research. Art is a human product; it is completely related to thinking, creativity, and imagination.
>
> PST #28 from pre VNOS-B: Science is objective, but art is subjective.
>
> PST #41 from pre VNOS-B: Science try to discover existing things, art try to show new things not known before.
>
> PST #45 from pre VNOS-B: In art, imagination has important role, we cannot use imagination in science.

Second, 5 (13, 52%) PSTs stated, "Scientists do not use creativity and imagination" in the pre-test, however, in the post-test nobody mentioned about this subcategory. For example:

PST #32 from pre VNOS-B: Scientists should not use their imagination, because science is not a branch to show creativity on human, it should be objective.

Third, while 10 (27 %) participants gave statements about "Scientists partially use creativity and imagination" these numbers decreased to 5 (12, 19 %) after intervention. For example:

PST #14 from pre VNOS-B: I do not think imagination is used while collecting data, but I think after data collection, creativity and imagination may be used.

PST #20 from pre VNOS-B: Scientists cannot use their creativity during planning and designing, but after data collection, they can use their creativity.

PST #28 from pre VNOS-B: Scientists do not use their creativity during data collection, but they may need during interpretation.

Furthermore, more PSTs showed adequate understanding about scientists use their creativity and imagination at the end of the intervention. For the subcategories the numbers and percentages increased from 20 (54%) to 38 (92, 60%) according to post VNOS-B results. For example:

PST #17 from post VNOS-B: Scientists use their creativity and imagination planning and investigating research.

PST #21 from post VNOS-B: Scientists use creativity and imagination during all of their work, when they are interpreting data, setting experimental design they use creativity.

In addition, after the intervention many PSTs realized that science and art are similar, the numbers and percentages increased from 20 (54%) to 36 (87, 80%) according to post VNOS-B results. For example:

PST #20 from post VNOS-B: Science and art are similar, constructing both of them we need creativity and originality.

PST #1 from post VNOS-B: Science and art are similar because both of them depend on creativity and imagination.

PST #36 from post VNOS-B: Science and art are similar. They are subjective and change by our views.

4.1.2.1.7 Socio-Cultural Effect

In order to display effectiveness of the intervention about view of socio-cultural effects on scientific knowledge Table 4.8 was designed. According to pre and post VNOS-B results, PSTs develop their understanding of socio-cultural effects on science.

Table4.8. Prevalent views about Socio-Cultural effects from pre and post VNOS-B

	Pre-test (37)	Post-test (41)
	Number (%)	Number (%)
Socio-Cultural factors affect scientific knowledge	5 (13,52 %)	17 (41,46 %)

According to Table 4.8, the numbers and percentages of PSTs increased from 5 (13, 52 %) to 17 (41, 46%). For example:

PST #33 from post VNOS-B: Scientists’ culture, beliefs, and background affect their hypotheses.

PST # 34 from post VNOS-B: Scientists can be affected their culture, beliefs, backgrounds, needs and previous theories.

PST #37 from post VNOS-B: Scientific knowledge is based on scientists’ cultural, political, religious, opinions etc.

PST #8 from post VNOS-B: Scientists are influenced by their culture, economical and social needs.

Although, there are some different subcategories about socio-cultural effect, in this part only pre and post VNOS-B results were presented. Other data sources such as interviews and reflection papers results will be present in next section. Moreover, the VNOS-B questionnaire does not includes any questions for socio-cultural effect.

4.1.2.2 Changes in Individual Participants' Views of NOS

In order to understand individual PSTs' developments in their understanding of NOS aspects Table 4.9 was constructed. This table shows changes for all of the PSTs' (34) views of NOS aspects. This table represents developments, declines and no changes from post VNOS-B according to pre VNOS-B results. It is important to note that the table shows only changes, not all of the views about NOS aspects. The pre and post VNOS-B results were compared according to NVivo data analysis program. According to this table, if a PST stated informed NOS view in the post test but did not state in the pre test, "+" was signed related NOS aspect. It means that for specific NOS aspect the PST had contemporary views after the intervention. If a PST did not shown in the post-test any development according to pre test result, "0" was signed related NOS aspect. It means that for specific NOS aspect the PST' views did not change. Moreover, if a PST stated misconception in the post test but did not state in the pre test, "–" was signed. It means that for specific NOS aspect the PST had some misconceptions after the intervention.

According to Table 4.9, all of the PSTs showed developments about many of the NOS aspects. For empirical basis of NOS, 14 PSTs developed their understandings according to pre VNOS-B scores. For observation and inference, 28 PSTs stated contemporary views. For theory and law, 32 PSTs changed their understandings informed views. For subjectivity, 28 PSTs developed their understanding. For tentativeness, 26 PSTs declared contemporary views. For creativity and imagination, 25 PSTs changed their understanding informed views. For socio-cultural effect, 15 PSTs showed development their understandings of NOS aspect. In the next part, these changes will be discussed in depth.

However, Table 4.9 also presents that two PSTs showed decline in their understanding of some aspect of NOS. One of them (PST #10) stated uninformed views about aspect of observation and inference. The PST stated that:

> PST #10 from post VNOS-B: Atom looks like this… Scientists are sure [about atom structure] by the [imagines obtained from] electron microscopes.

She or he did not mention anything about scientific knowledge is observable and scientists can be sure in the pre VNOS-B.

Table 4.9. Each PST' development NOS views from VNOS-B

Participants # Aspects of NOS	1	2	3	4	5	7	9	10	11	12	13	14	15	18	20	22	23	25	26	28	29	30	31	32	33	34	35	36	38	39	40	41	44	45
Empirical NOS	+	0	+	0	0	0	+	0	+	0	0	+	0	+	+	+	+	0	+	+	0	0	0	+	+	0	0	0	-	0	0	0	+	0
Observation-Infer	+	+	0	+	+	+	+	-	+	0	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	0	+	+	0	+	+	+	+
Theory & Laws	+	+	+	+	+	+	+	+	+	+	+	+	+	0	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Subjectivity	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	0	0	0	0	+	+	+	+	+	+	+	+	+	+	0	+	+	+	+
Tentativeness	+	0	0	0	0	+	+	+	+	+	0	+	0	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	0	+	+	+
Creativity	+	+	+	0	+	0	+	+	+	+	0	+	0	+	+	+	+	+	+	+	+	0	+	+	+	+	0	+	+	+	0	+	0	0
Socio-Cultural	0	+	+	+	+	0	0	+	+	+	+	+	0	0	+	0	+	0	0	0	+	0	0	0	+	+	0	0	+	0	0	0	0	0
Total	5	5	5	4	5	4	6	5	7	5	4	7	3	5	6	5	6	3	4	6	6	4	5	6	7	6	3	5	6	3	3	5	5	4
								-1																					-1					

+ indicates a change in views /developed understanding of NOS aspect after the intervention

0 indicates no change in participant's views of NOS aspect after the intervention

-indicates a misconception about NOS aspect after the intervention

The other PST showed uninformed views about aspect of empirical bases of NOS. While answering the post VNOS-B the PST stated that:

> PST #38 from post VNOS-B: Opinions are totally subjective, but scientific knowledge is more objective.

The PST did not point out anything related to objectivity of scientific knowledge in the pre application of VNOS-B.

Individual PSTs' developments in terms of understanding NOS aspects were investigated using their answers for the pre and post VNOS-B questionnaire. The pre test was applied at the beginning of intervention and the post-test was applied at the end of the semester. PSTs' answers were assigned as inconsistent, transitional, and consistent according to science education reforms. In order to show changes some tables were constructed for each aspect of NOS. These tables represent 34 PSTs' statements, because 11 PST (7 pre; 4 post) did not complete the VNOS-B in the laboratory. Therefore it could not be compared these PSTs' pre and post VNOS-B results.

4.1.2.2.1 Empirical Basis of NOS

In order to show changes of PSTs' views about the aspect of empirical basis of scientific knowledge Table 4.10 was designed. According to this table, PSTs showed some developments from inconsistent to transitional and to consistent. For example, one of them stated about 'scientific knowledge is subjective';

> PST #33 from pre VNOS-B: "Science depends on experiment, everything should have reasoning explanation," and "Scientific knowledge is absolutely true"

However, the same PST did not write any statement about ‘scientific knowledge is subjective’ in the post VNOS-B application. This development was accepted from inconsistent to transitional level and nine PSTs showed similar development.

According to the Table 4.10, there are some developments from transitional to consisted level. For example, PST #11 did not express any statement about ‘empirical evidence for scientific knowledge’ in the pre VNOS-B application. However, the same PST stated about ‘empirical evidence for scientific knowledge’:

> PST #11 from post VNOS-B: “Scientific knowledge is based on empirical evidence” and “Scientific knowledge is reached by scientists and they do some experiments”.

This development was accepted from transitional to consistent level and five PSTs showed similar development.

Table 4.10. Changes in PSTs' views of the aspect of empirical basis

		POST VNOS-B		
		Inconsistent	Transitional	Consistent
PRE VNOS-B	Inconsistent	5	9	0
	Transitional	1	13	5
	Consistent	0	0	1

Although PSTs gained some developments about the empirical aspect, some of the PSTs did not gain any development. For example, five PSTs hold their same inconsistent views according to pre and post VNOS-B test. In addition, 13 PSTs did not change their transitional views about the empirical aspect. Furthermore, one of the PSTs’ (PST #38) views were changed from transitional to inconsistent. Although the PST did not state any view about 'scientific knowledge is subjective' in the pre VNOS-B test, the PST expressed below statement at the end of the semester.

> PST #38 from post VNOS-B: Opinion is totally subjective, but scientific knowledge is more objective

This change was accepted as a recession for the PST.

According to Table 4.10, many PSTs (19) of the sample (34) did not develop their views about the empirical basis aspect of NOS. There can be some reasons to explain this situation; one of them is that in order to develop PSTs' views of empirical basis of NOS aspect some experiments were done in the laboratory. Because of PSTs were familiar reaching scientific knowledge by means of experiments from their educational life, perhaps they did not feel need for any changing. For such similar situations, Clough (2006) suggested that students think their ideas match the new situations. Therefore, they do not change their previous ideas. Possible reasons for the lack of change in PSTs' views will be explored more deeply in the next chapter.

4.1.2.2.2 Observation & Inference

In order to illustrate changes of PSTs' views about the aspect of observation and inference Table 4.11 was constructed. According to this table, PSTs have some developments from inconsistent to transitional and to consistent. For example, PST #29 stated about 'scientific knowledge is observed' that;

> Part #29 from pre VNOS-B: Atom looks like solar system, developed technology promote finding the structure of atom.

After the intervention the same PST expressed about ‘scientific knowledge is inferred’ that;

> PST #29 from post VNOS-B: It [atom] looks like solar system. Scientists make some research and experiment. Then they make inferences about structure of atom.

This development was accepted from inconsistent to transitional level and 22 PSTs showed similar development.

Table 4.11. Changes in PSTs’ views of the aspect of observation and inference

		POST VNOS-B		
		Inconsistent	Transitional	Consistent
PRE VNOS-B	Inconsistent	2	22	3
	Transitional	1	3	3
	Consistent	0	0	0

According to the Table 4.11, three PSTs showed developments from inconsistent to consisted level. For example, PST #1 did not express any statement about ‘importance of models in science’ and ‘scientific knowledge is inferred’ in the pre VNOS-B application. However, the same PST stated for the same subcategories that;

> PST #1 from post VNOS-B: [Atom] like little balls. Because they [scientists] make a lot of observations, prediction, and inference.

Three PSTs showed developments from transitional to consisted level according to the table. For example, PST #13 did not express any statement about ‘observation and inference are difference’ in the pre VNOS-B application. However, the same PST stated for the same subcategory that;

PST #13 from post VNOS-B: Their [scientists] conclusions are affected by the scientists' imaginary, creativity. They are different persons and they have different thinking perspectives. The observation and inference are different things.

Although many PSTs gained some developments about the observation-inference aspect, some of the PSTs did not gain any development. According to the Table 4.11, two PSTs hold their same inconsistent views according to pre and post VNOS-B test. In addition, three PSTs did not change their transitional views about the observation-inference aspect. Furthermore, one of the PSTs (PST #10) view was changed from transitional to inconsistent understanding level. Although the PST expressed about 'observation and inference are difference' in the pre VNOS-B test:

PST #10 from pre VNOS-B: Different scientists can derive different results from the same data, because of their interpretations are different.

The same PST did not state any view about the same category in the post VNOS-B test.

4.1.2.2.3 Theory & Law

In order to demonstrate changes of PSTs' views about the aspect of theory and law Table 4.12 was designed. According to this table, PSTs have some developments from inconsistent to transitional and to consistent understanding level. For example, PST #44 expressed about 'roles of theory and law to understand nature' that;

PST #44 from pre VNOS-B: Laws cannot change, but theory can change. If we want to understand nature we must accept some thing as constant, these are laws.

However, after the intervention the same PST stated that:

> PST #44 from post VNOS-B: Law is a general explanation what happens in nature, but theory gives explanations about natural phenomena, and try to answer why that event occur.

for the same subcategory of theory and law aspect. This development was accepted from inconsistent to transitional understanding level and 22 PSTs showed this development.

Table 4.12. Changes in participants' views of the aspect of theory and law

		POST VNOS-B		
		Inconsistent	Transitional	Consistent
PRE VNOS-B	Inconsistent	1	22	10
	Transitional	0	1	0
	Consistent	0	0	0

According to the Table 4.12, there are 10 PSTs showed developments from inconsistent to consisted understanding level. For example, PST #12 stated about ‘differences between theory and law’ that;

> PST #12 from pre VNOS-B: Of course, there is [difference between theory and law]. For example; while there is still a debate about whether the evolution theory is true or not, Newton’s laws cannot be changed”

However, the same PST stated for same subcategories after the intervention that;

> PST #12 from post VNOS-B: Yes, [they are different], theory is the explanation of the law and law states the relations between the ideas and variables. They cannot translate into another. They can change when new information is added.

Although many PSTs have developed their understanding about the theory and law aspect, two of the PSTs did not gain any development. According to the

Table 4.12, one of the PSTs held his/her same inconsistent views according to pre and post VNOS-B test. In addition, one of them did not change his/her transitional views about the theory and law aspect.

4.1.2.2.4 Subjectivity

In order to display changes of PSTs' views about the aspect of subjectivity Table 3.13 was constructed. According to this table, PSTs have some developments from inconsistent to transitional and to consistent understanding level. For example, PST #20 expressed about 'scientists' different background affect their work' that;

> PST #20 from pre VNOS-B: Scientists have a lot of common points, but sometimes they think differently

However, after the intervention the same PST stated that,

> PST #20 from post VNOS-B: This different point of view is embedded in nature of science. Constructing scientific knowledge is subjective, scientists have different prior knowledge and beliefs and use them while interpreting the science concepts, and they interpret the same data, in a different way because of their pre-knowledge and beliefs.

for the same subcategory of subjectivity aspect. This development was accepted from inconsistent to transitional understanding level and 13 PSTs showed similar development.

According to the Table 4.13, there are eight PSTs showed developments from inconsistent to consisted understanding level. For example, PST #7 did not express any statement about 'theory-laden of scientific knowledge' in the pre VNOS-B application. However, the same PST stated about ‘theory-laden of scientific knowledge’;

> PST #7 from post VNOS-B: Science is theory-laden, in other words it can be interpreted differently by different scientists. Seeing the same things does not mean to conclude the same things.

This development was accepted from transitional to consistent level and eight PSTs showed similar development.

Table 4.13. Changes in PSTs' views of the aspect of subjectivity

		POST VNOS-B		
		Inconsistent	Transitional	Consistent
PRE VNOS-B	Inconsistent	1	13	8
	Transitional	0	5	7
	Consistent	0	0	0

Seven PSTs showed similar developments from transitional to consisted level according to the Table 4.13. For example, PST #45 did not express any statement about ‘subjectivity and theory-laden of scientific knowledge’ in the pre VNOS-B application. However, the same PST stated for the same subcategory that;

> PST #45 from post VNOS-B: Scientific knowledge is theory-laden, so scientists may start with different theories, thus they may support different theories. Moreover, science is also subjective; it [science] changes from scientists to scientists.

Although many PSTs have developed their understanding about the subjectivity aspect, some of the PSTs did not gain any development. According to the Table 4.13, one of the PST held his/her same inconsistent views according to pre and post VNOS-B test. Moreover, five PSTs did not change their transitional views about the subjectivity aspect.

4.1.2.2.5 Tentativeness

In order to show changes of PSTs' views about the aspect of tentativeness Table 4.14 was constructed. According to this table, PSTs have some developments from inconsistent to transitional and to consistent understanding level. For example, PST #29 expressed about 'tentativeness of theories' that;

PST #29 from pre VNOS-B: Theories can change, but it requires time.

However, after the intervention the same PST stated that;

> PST #29 from post VNOS-B: I think theories are changeable. I think that to develop the scientific knowledge, we should learn scientific theories. In other words, science is theory-laden. Scientists make new research, experiments based on prior theories.

for the same subcategory of tentativeness aspect. This development was accepted from inconsistent to transitional understanding level and 22 PSTs showed similar development.

According to the Table 4.14, one of the PSTs showed developments from inconsistent to consisted understanding level. The PST #35 did not express any statement about 'tentativeness of scientific knowledge and theories' in the pre VNOS-B application. However, the same PST stated about 'tentativeness of scientific knowledge and theories';

> PST #35 from post VNOS-B: Theories can be changed by the development science and technology. We teach scientific theories because; the theories should be known until the new theory exists.

Table 4.14. Changes in PSTs' views of the tentativeness aspect

		POST VNOS-B		
		Inconsistent	Transitional	Consistent
PRE VNOS-B	Inconsistent	3	22	1
	Transitional	0	5	3
	Consistent	0	0	0

Three PSTs showed similar developments from transitional to consisted understanding level according to the Table 4.14. For example, PST #11 stated about ‘tentativeness of scientific knowledge and theories’ that,

> PST #11 from pre VNOS-B: Theories are hypotheses, which may not be surely accepted. That is, they can change. However, a theory is accepted by means of many experiments.

However, after the intervention the same PST stated for the same subcategory that;

> PST #11 from post VNOS-B: Theories can change. Because there could be some developments of technology that scientists use to receive scientific knowledge; so scientists have different results and they change theories. That is, scientific knowledge is tentative.

Although many PSTs have developed their understanding about the tentativeness aspect, some of them did not gain any development. According to the Table 4.14, three PSTs hold their same inconsistent views according to pre and post VNOS-B test. Moreover, five PSTs did not change their transitional views about the tentativeness aspect.

4.1.2.2.6 Creativity & Imagination

In order to express changes of PSTs' views about the aspect of creativity and imagination Table 4.15 was constructed. According to this table, PSTs have some developments from inconsistent to transitional and to consistent understanding level. For example, PST #35 expressed about 'scientists use creativity and imagination' that;

> PST #35 from pre VNOS-B: I think scientists should not use their imagination while collecting data, they should be objective. In this way, they can reach true results.

However, after the intervention the same PST stated that;

> PST #35 from post VNOS-B: Scientists use their creativity and imagination during and after data collection. According to their findings, scientists make inferences

for the same subcategory of creativity and imagination aspect. This development was accepted from inconsistent to transitional understanding level and three PSTs showed similar development.

Table 4.15. Changes in PSTs' views of the creativity and imagination aspect

		POST VNOS-B		
		Inconsistent	Transitional	Consistent
PRE VNOS-B	Inconsistent	0	3	7
	Transitional	0	4	15
	Consistent	0	0	5

According to the Table 4.15, seven PSTs showed similar developments from inconsistent to consisted understanding level. For example, PST #33 stated about 'using creativity and imagination in science' that;

> PST #33 from pre VNOS-B: “Science depends on experiments, everything should have reasoning explanation,” and “Scientific knowledge is absolutely true.”

However, after the intervention the same PST stated that;

> PST #33 from post VNOS-B: “In science we make observations of natural phenomena then by using our creativity we interpret these observations and construct scientific knowledge” and “Scientist use their creativity and imagination during the scientific investigation, thus they can be reach different results”

for the same subcategory of creativity and imagination aspect.

Fifteen PSTs gained similar developments from transitional to consisted understanding level according to the Table 4.15. For example, PST #28 expressed about ‘using creativity and imagination in science’ that,

> PST #28 from pre VNOS-B: Scientists do not use their creativity during data collection, but they may need them during interpretation [of data].

However, after the intervention the same PST stated for the same subcategory that;

> PST #28 from post VNOS-B: Scientists use creativity and imaginations. They do experiment and in some situations which there is no way to observe using five senses, making inferences, and these inferences include imagination and creativity.

Although many PSTs have developed their understanding about the creativity and imagination aspect, some of them did not gain any development. According to the Table 4.15, four PSTs hold their same transitional views according to pre and post VNOS-B test. In addition, five PSTs had consisted views about this aspect before and after the intervention.

4.1.2.2.7 Socio-Cultural Effect

In order to present changes of PSTs' views about the aspect of socio-cultural effect Table 4.16 was constructed. According to this table, PSTs have some developments from inconsistent to transitional and to consistent understanding level. For example, PST #2 did not express any statement about 'socio-cultural effect in science' in the pre VNOS-B application. However, the same PST stated for the same subcategory that;

> PST #2 from post VNOS-B: [Scientists think differently] because each of them have different ideas about the same event.

This development was accepted from inconsistent to transitional understanding level and seven PSTs showed similar development.

Table 4.16. Changes in PSTs' views of the socio-cultural effect

		POST VNOS-B		
		Inconsistent	Transitional	Consistent
PRE VNOS-B	Inconsistent	18	7	6
	Transitional	0	1	2
	Consistent	0	0	0

According to the Table 4.16, six PSTs showed similar developments from inconsistent to consisted understanding level. For example, PST #14 did not articulate any statement about 'socio-cultural effect in science' in the pre VNOS-B application. However, the same participant stated for the same subcategory that;

> PST #14 from post VNOS-B: They [scientists] are different person; [their] conclusions can be different or similar but not the same. Scientists' expectations, education, beliefs affect the way they are working.

Two PSTs gained similar developments from transitional to consisted understanding level according to the Table 4.16. For example, PST #34 expressed about 'socio-cultural effect in science' that;

> PST #34 from pre VNOS-B: Data are same, but interpretations depend on person and they are different. Scientists have different background thus their interpretations are different.

However, after the intervention the same PST stated for the same subcategory that;

> PST #34 from post VNOS-B: Scientists can be affected by their culture, beliefs, backgrounds, needs, and previous theories. Thus, with some experiment and data scientists can reach different results.

According to Table 4.16, many PSTs (18) of the sample (34) did not develop their inconsistent views about the aspect of socio-cultural effect in science. In addition, one PST held his/her same transitional views according to pre and post VNOS-B test.

4.1.2.3 Summary

At the end of this part, it can be said that, many PSTs have develop their understanding levels of each aspect of nature of science. However, especially for two aspects, which are the empirical basis and socio-cultural effect PSTs generally resisted to change their previous views. According to Table 4.10 and Table 4.16, unfortunately these unchanged views generally inconsistent and transitional views. In the next chapter, possible reasons of these situations will be discussed deeply.

4.1.3 Connections Made among Various Aspects of NOS

As it was mentioned before, there is not a single definition of NOS, which represents all scientific knowledge and science enterprises. However, there is a consensus of NOS definition about K-12 education, for example; scientific knowledge is tentative, and this aspect includes laws, theories, and facts (Irez, 2006; Lederman, 1992; Lederman & Abd-El-Khalick, 1998). For example, Tentativeness is one of the central aspects of NOS. Moreover, tentativeness is related to other NOS aspects represent that scientific knowledge is subject to change. It is related to,

> (a) scientific knowledge has a basis in *empirical evidence*, (b) empirical evidence is collected and interpreted based on current scientific perspectives (*subjectivity, or theory-laden observations and interpretations)* as well as *personal subjectivity* due to scientists' values, knowledge, and prior experiences, (c) scientific knowledge is the product of human *imagination and creativity*, and (d) the direction and products of scientific investigations are influenced by the society and culture in which the science is conducted *(socio-cultural embeddedness*)" (Schwartz & Lederman, 2002, p. 207).

As shown in this example, connections promote understanding of NOS in a more robust way.

Furthermore, some researchers claim that individual aspects of NOS by themselves do not represent the nature of science. It is not easy to describe specific NOS aspects as being distinct from one another (Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003).

In this study, there was not any specific question regarding the PSTs' ability to recognize the relatedness of NOS aspects before and after the intervention. However, during the data analyses, findings showed that some of the PSTs made connections between NOS aspects. These connections were more common in post-semester data. According to the data analysis, total180 statements indicated connections between one or more aspects of NOS. These statements were collected from different data sources; 7 of them from pre-VNOS-B; 81 of them from post-VNOS-B; 36 of them from reflection papers; and 55 of them from interviews. Table 4.17 shows these connections according to seven NOS aspects. Before the intervention, only seven statements were determined in pre-VNOS-B application. These statements were written by different seven PSTs. However, at the end of the intervention the statements number increased to 81 statements made by 43 PSTs, except that PST #2 and PST #22.

Table 4.17.Statements for connections among NOS aspects

	1	2	3	4	5	6	7
1. Empirical Basis of NOS	-----	-----	-----	-----	-----	-----	-----
2. Observation & Inference	15	-----	-----	-----	-----	-----	-----
3. Theory & Law	0	2	-----	-----	-----	-----	-----
4. Subjectivity	0	25	0	-----	-----	-----	-----
5. Tentativeness	3	4	0	7	-----	-----	-----
6. Creativity & Imagination	35	28	0	30	2	-----	-----
7. Socio-Cultural Embeddedness	5	3	0	15	3	3	-----

There can be some explanations for these connections. During the intervention, each NOS aspect was targeted separately. However, NOS characteristics are related to each other, they are engaged. In addition, every week there were discussion parts at the end of the activities, and PSTs reflected their ideas about the connections of NOS aspects. The instructors did not impede the PSTs ideas and they did not guide about these connections.

4.1.3.1 Pre Semester Connections among NOS Aspects

At the beginning of the semester, only seven statements were determined in pre-VNOS-B application. These statements were written by different seven PSTs.

4.1.3.1.1 Connecting the Empirical NOS with Creativity and Imagination

Five of the seven statements from pre-intervention data were related to the connection between empirical basis of NOS and creativity-imagination. Generally, PSTs emphasized that during the experiment process scientists are affected their creativities and imaginations. Below there are two quotations, which represent of this connection.

> PST #23 from pre VNOS-B: In science, we can trust experiments and their results, but during experiment, creativity may affect the process.

> PST #4 from pre VNOS-B: Of course, they [scientists] use their imagination not only while collecting data but also during the all steps of research because the imagination and creativity are the way of explanations. For photosynthesis experiment, it was the result of imagination to find electrons came from water.

According to Table 4.17, the PSTs declared 29 statements after the intervention, all of them from post VNOS-B questionnaire. Some of the PSTs focused on using creativity and imagination before designing experiments. For example:

PST #37 from post VNOS-B: Today, most of technological developments we use were just a dream once. However, scientists dream that, they use their creativity and imagination they built experimental designs by using their creativities and get the scientific knowledge.

PST #5 from post VNOS-B: First, a scientist imagines and wonder than s/he investigate and do experiment, and then collect data.

PST #4 from post VNOS-B: Of course, scientists use their creativity. Designing the experiment requires creativity; in the light of this creativity, the experiment is defined.

Some others emphasized that scientists use their creativity and imaginations during and after the experimental process. Below, there are some quotations, which represent of this connection.

PST #43 from post VNOS-B: Scientists use their imagination and creativity during and after data collection. For example, with available materials, they can set up different experiment design and they can infer their data according to their creativity and imagination.

PST #11 from post VNOS-B: Scientists also use their creativity and imagination during and after data collection. Because science requires both experiments and creativity.

PST #20 from post VNOS-B: Scientists use their creativity and imagination during and after data collection. While constructing atom models, scientists collect data, performs experiment finally, they use their creativity and imaginations.

PST #21 from post VNOS-B: Scientists use creativity and imagination during all of their work. When they are interpreting data, setting experimental design they use creativity.

4.1.3.1.2 Connecting the Subjectivity with Creativity and Imagination

According to pre VNOS-B analysis, two of the seven statements were related to the connection between subjectivity and creativity-imagination. Both PSTs emphasized that scientists' works are subjective because scientists use their creativity and imagination. Below, there are two quotations:

> PST #3 from pre VNOS-B: The reasons why there are different conclusions may be because of scientists' views to events, doing experiments in different conditions and using different data, and because of the fact that every scientists have their own different background, knowledge, ideas, and creativity.

> PST #40 from pre VNOS-B: Scientists can make different interpretations using same data. In addition, this can be related scientists' imaginations.

According to Table 4.17, the PSTs declared 28 statements after the intervention about the connection between subjectivity and creativity-imagination; these statements were collected from different data sources; 18 of them from post-VNOS-B; 8 of them from reflection papers; and 2 of them from interviews. Some of the PSTs focused on subjectivity of scientific knowledge because of using creativity and imagination. Below, there are some quotations, which represent of this connection.

> PST #35 from post VNOS-B: Scientists are subjective, so they can make different conclusions. Scientists have different imagination, knowledge background, so these factors affect the conclusions that they make.

> PST #30 from post VNOS-B: Scientists have different creativity and imagination, also they have different backgrounds, and thus their interpretations are different.

PST #9 from post VNOS-B: Science is subjective, because scientists use their creativity to reach scientific knowledge.

One of the PSTs stated that subjectivity might affect scientists' creativity; s/he expressed that:

PST #10 from interviews: Scientists' background knowledge can affect their creativity and their imagination.

Some of the PSTs mentioned about laboratory activities and connection between subjectivity and creativity. Below, there are two excerpts, which represent of this connection.

PST #43 from reflection paper: While interpreting data scientists use their prior knowledge, their creativity, and imaginations. In our today's lab, we observed the fossil pictures and according to our observation, we made some inferences about organism of fossils and its environment, then we draw their pictures.

PST #28 from reflection paper: While producing scientific knowledge, scientists use their creativity and imaginations. Every scientist can infer different things from the same data. Since they do not know the truth absolutely, they use their creativity. While using creativity, scientists do not do it just by their imagination. They based on their imaginations to some reality. In addition, they have logical reasoning. They use their imagination while interpreting data. This week, we are given a little part of a fossil. Moreover, we were expected to complete it and find the whole body of living and its living environment. We all reached different conclusions from the same fragments. Since our imaginations, observations, and prior knowledge are different, we reached different conclusions.

Some other PSTs focused on individual differences for subjectivity and creativity for scientific knowledge. For instance:

PST #25 from reflection paper: Science is affected from scientists' prior knowledge, experiences, and especially their creativity and imagination. Thus, we cannot see science as certain. Because, it is made by human being.

PST #5 from reflection paper: Scientific knowledge is subjective because it changes with respect to the scientists' imaginations.

Another example, one PST expressed that the relationship the Real Fossil activity and subjectivity of scientific knowledge:

> PST #26 from interview: I think individual differences affect science. We draw different creatures from same fossils, because everybody has different creativity and imagination. Scientists' believes of religions and cultures can affect their imagination.

In this statement, the PST focused on some possible reasons for different creativity and imagination. For example, culture and religion may affect scientists' creativity, thus it can be related to subjectivity of scientific knowledge.

4.1.3.2 Post Semester Connections among NOS Aspects

At the end of the semester, total173 statements indicated connections between one or more aspects of NOS.

4.1.3.2.1 Connecting the Empirical NOS with Observation and Inference

In this part, there are some connections, which determined by PSTs after the intervention between NOS aspects. First, it is about connection between empirical basis of scientific knowledge and observation-inference aspect. Although there was no connection between these aspects before the intervention, after the intervention 15 statements were determined. These statements were collected from two different data sources; 14 of them from interviews and one of them from reflection papers. Generally, PSTs focused on an importance of experiment for science and especially an importance of observation. Below, there are three statements, which represent of this connection.

> PST #11 from interviews: I think experiment is very important for learning scientific knowledge. During experimentation, students can do and observe all of the process.

> PST #28 from interviews: Learning by conducting experiments is more effective, because students can observe and can do, thus they can discover scientific knowledge like scientists.

> PST #8 from interviews: Experiment has main role in science. Observation and experiment are necessary for science.

Another PST commented that observation in the Black Box activity is related to empirical nature of scientific knowledge is based on evidence and observations of the natural world:

> PST #4 from interview: I think observation is most important not only scientific research but also our daily life. During observation, we can understand our environment and its needs. For example, in the laboratory class, we observed the black box, then we inferred about inside the box. If we did not observe we could not infer inside the black box.

The PST expressed that observation is important not only for making inferences but for also conducting experiments. According to the PST, observation is the main skill used to understand nature.

Moreover, some of the PSTs emphasized the activity, which they did in the laboratory about this connection. For example,

> PST #41 from interviews: During photosynthesis and germination experiments we observed all process, we observed and we did some times, thus we learned.

> PST #45 from interviews: During experiments, we can easily understand because we can observe. In the laboratory, we did

> photosynthesis experiment we observed starch in leaves and we reached the results.

Lastly, one PST stated in the reflection paper that:

> PST #1 from reflection paper: In this week we directly made an experiment and directly observed that the thing which affects photosynthesis. By this way, we gained evidence in ourselves and observed empirical basis.

4.1.3.2.2 Connecting the Empirical NOS with Tentativeness

Another connection between NOS aspects is empirical basis of scientific knowledge and tentativeness. One of the PSTs emphasized the connection:

> PST #11 from post VNOS-B: Scientific knowledge is less tentative than opinion, because, scientific knowledge based on experiments.

> PST #11 from post VNOS-B: Theories can change. Because there could be some developments of technology that scientists use to receive scientific knowledge; so scientists have different results and they change theories. That is, scientific knowledge is tentative.

4.1.3.2.3 Connecting the Empirical NOS with Socio-Cultural Embeddedness

Another connection was detected between empirical basis of scientific knowledge and socio-cultural embeddedness. According to Table 4.17, there are five statements about this connection. All of the statements were form post VNOS-B instrument. Generally, the PSTs mentioned about the effects of socio-cultural structure on empirical basis of science. Below there are three statements, which represent of this connection.

> PST #43 from post VNOS-B: Different scientists can reach different conclusions. Because, all are different person their beliefs, [.....] societies are different. Thus, they can reach different conclusions with same experiment and same data.

> PST #43 from post VNOS-B: Scientists can be affected by their culture…. Thus, with the same experiment and data scientists can reach different results.

> PST #11 from post VNOS-B: Because of scientists, have different cultures and societies... Their educational background is also different. Therefore, although they conduct the same experiments and collect the same data, they make inference in a different way.

4.1.3.2.4 Connecting the Observation and Inference with the Theory and Law

Another connection was determined between theory-law and observation-inference. According to Table 4.17, there are two statements about this connection. These PSTs focused on the activity, that done in the laboratory. These are:

> PST #26 from reflection paper: We cannot observe the collusion of molecules. We just infer. In this week activity, we observed the relationship between pressure of gas and volume of gas.

> Another PST stated after the activity related to observation-inference that;

> PST #25 from interviews: This activity reminded me the relationship between theory and law, for one law there can be some explanations, which are accepted as theories.

The PST connected laws with observations and connected theories with inferences.

4.1.3.2.5 Connecting the Subjectivity with the Observation and Inference

Another connection was detected between subjectivity and observation-inference. According to Table 4.17, there are 25 statements about this connection. These statements were collected from different data sources; 4 of them from reflection papers; and 21 of them from interviews. Many of the PSTs mentioned about the laboratory activity and made a connection. Below, there are some quotations, which represent of this connection.

> PST #12 from interviews: In laboratory, we observed same thing, but our inferences about it were different. This can be related to our background knowledge or different viewpoints.

> PST #18 from interviews: Every group designed different structures, because our backgrounds were different, so our inferences were different.

> PST #29 from interviews: In laboratory, we observed a box, and then every group designed different structures. I think this is related to subjectivity, our inferences were different. After this activity, firstly I suspected reliability of scientific knowledge not at all but for some parts.

> PST #3 from interviews: While doing observation we are affected from our background knowledge, according to this knowledge we observe. We observe according to our goals, we select something from other things to observe.

Another PST articulated that the Black Box activity is related to subjectivity; especially it is related to personal preferences:

> PST #29 from interview: Observation and inference are very important for scientific knowledge. In laboratory, we observed a box, and then every group designed different structures. I think this is related to subjectivity, our inferences were different. After this activity, firstly I suspected reliability of scientific knowledge, not at all scientific knowledge but for some parts.

The PST focused on a relationship between inferences and subjectivity, this cause suspicious toward scientific knowledge.

4.1.3.2.6 Connecting the Creativity and Imagination with the Observation and Inference

Some of the PSTs focused on the effects of creativity on observation and inferences. Below, there are three quotations, which represent of this connection.

> PST #14 from interviews: I understand that scientists can have different inferences about same thing. In addition, I understand that there could be different ways to reach the same conclusion.

> PST #9 from reflection paper: Scientists provide many theories about a scientific knowledge, then they observe as theories, but their observations and their studies are affected by their prior theories, prior knowledge, beliefs, etc. Thus, scientists reach different conclusions. Therefore, they have different inferences.

> PST #26 from reflection paper: Inferences are interpretations of observations and depend on our prior knowledge and experience.

Another example, one PST expressed that the relationship the Black Box activity and creativity and imagination aspects of scientific knowledge:

> PST #9 from interview: I think it [Black Box] can be related to creativity, because people can have different creativities. In the past about atom, different scientists inferred different atom models.

The PST focused the relevance between inferences and creativity. This relationship is important because while scientists infer about something they use their creativity and imagination. Moreover, different scientists can develop different inferences, this can improve scientific developments.

4.1.3.2.7 Connecting the Tentativeness with the Observation and Inference

Another connection was detected between tentativeness and observation-inference. There are four statements about this connection, two of them from interviews and two of them from reflection papers. The PSTs emphasized that this connection after the laboratory activities. Below, there are two quotations, which represent of this connection.

> PST #30 from interviews: Each group designed different system, all of them were right. I think this can be related to tentativeness of scientific knowledge.

> PST #27 from reflection paper: In this activity, I show that the scientific knowledge is tentative. I mean, first I had some fossils. I observed them, and then I made prediction about their age.

4.1.3.2.8 Connecting the Socio-Cultural Embeddedness with the Observation and Inference

Another connection was detected between socio-cultural embeddedness and observation-inference. There are three statements about this connection, two of them from interviews and one of them from post VNOS-B instrument. The PSTs focused on the effect of socio-cultural structures on observation and inferences. For example:

> PST #23 from post VNOS-B: It [culture] affects scientists' observations, inferences and their predictions.

> PST #1 from interviews: Different inferences depend on different background of people and different socio-cultural structures.

4.1.3.2.9 Connecting the Tentativeness with the Subjectivity

Another connection was detected between subjectivity and tentativeness. There are seven statements about this connection, three of them from reflection papers and four of them from post VNOS-B instrument. The PSTs emphasized that scientific knowledge is subject to change and one of the changing reason is subjectivity. Below, there are three statements, which represent of this connection.

> PST #1 from reflection paper: We know that scientific knowledge can be tentative so every scientist even every work can make their inferences because inferences depend on their interpretations. If we observe something, we can think different or we can have different ideas. Therefore, these things make scientific knowledge subjective.

> PST #12 from post VNOS-B: Scientific knowledge is theory-laden, and it is tentative. It can be change according to scientists' background knowledge, creativity, different inferences etc. Therefore, although they look at the same data they may come up with different conclusions.

> PST #1 from post VNOS-B: Scientific knowledge is subjective; it means it can be changed (tentative) by scientists' opinions and predictions, and inferences. Therefore, scientists can reach different conclusions by observing or interpreting from the same phenomena (theory or law).

4.1.3.2.10 Connecting the Socio-Cultural Embeddedness with the Subjectivity

Another connection was detected between subjectivity and socio-cultural embeddedness. According to Table 4.17, there are 15 statements about this connection. These statements were collected from different data sources; 2 of them from reflection papers; 2 of them from interviews; and 11 of them from post VNOS-

B instrument. Many of the PSTs focused on socio-cultural effects on subjectivity of scientific knowledge. For example:

> PST #11 from post VNOS-B: Scientists have different cultures, societies, and personalities, also their educational backgrounds are different. Therefore, although they observe the same experiments and data, they make inference in some different ways.
>
> PST #24 from interviews: Scientists use their background knowledge and they are affected from cultural-social structure.
>
> PST #14 from reflection paper: Scientific knowledge is affected by the social and cultural structures of scientists. The needs of society, characteristics of people, lifestyles, and religion affect science.

4.1.3.2.11 Connecting the Tentativeness with the Creativity and Imagination

According to the data analysis, the connection between creativity and tentativeness were detected. There are two statements, they are from interviews and reflection papers, and therefore they were stated after the intervention. The PSTs emphasized that creativity for tentativeness of scientific knowledge. Below, there are two statements, which represent of this connection.

> PST #39 from reflection paper: Scientific knowledge can be changed also via scientists' inferential, creative, social and cultural embedded.
>
> PST #31 from interviews: I think this [the observation-inference activity] can be related to creativity, and I saw that scientific knowledge is not absolute.

4.1.3.2.12 Connecting the Socio-Cultural Embeddedness with the Tentativeness

According to Table 4.17, the PSTs declared three statements after the intervention about the connection between tentativeness and socio-cultural embeddedness; two of them from interviews and one of them from reflection papers. The PSTs focused on socio-cultural effects for tentativeness of scientific knowledge. For example:

> PST #38 from interviews: Scientific knowledge can be changed, because more people made investigations continuously using different methods and different scientists can find new things and science is developed. Imagination, religion, geographic environment, and culture affect science.

> PST #38 from interviews: I think scientific knowledge is changeable by means of new scientific knowledge and technological developments. In addition, I think culture can change science.

4.1.3.2.13 Connecting the Socio-Cultural Embeddedness with the Creativity and Imagination

The last connection was detected between creativity-imagination and socio-cultural embeddedness. There are three statements about this connection and these are from post VNOS-B instrument. The PSTs focused on the relationship between creativity and socio-cultural effects for scientific knowledge. For example,

> PST #17 from post VNOS-B: Creativity is important of both science and art… In addition, culture has effects on them equally.

> PST #13 from post VNOS-B: Both of science and art have creativity of the person. Both of them are affected social and cultural environment.

The fact that some students made additional connections to other aspects of NOS that were not explicitly targeted in the activities is encouraging, this is indicative of a more robust understanding of the nature of science.

4.2. Research Question 2

In this section, the second research question and sub-questions were analyzed, which factors affected PSTs' understandings of NOS views, and PSTs' perspectives about future science teaching. Findings are organized and presented in terms of the aspects of NOS examined in the study.

4.2.1 Preservice Science Teachers' Perspectives and Experiences

In this part, there are some findings about PSTs' perspectives and experiences related to their learning in the intervention. At the end of the course, the interviews were conducted with PSTs. According to the interviews analyses 43 (95,6 %) PSTs declared orally, their views about NOS were changed at the end of the semester.

Below there are some statements from interviews:

> PST #13: I liked this course, after the laboratory, I learned many new things about science. Before this course, I took some laboratory courses, but this course was different.
>
> PST #14: In this course every week, I learned different things about science and I was surprised, my old views changed.
>
> PST #20: Before this course, I did not know NOS aspects. However, science has its nature from beginning; we were not taught about this subject. In this laboratory, I learned many new things about science. I liked this course.

PST #33: Before this semester I did not know anything about NOS, my views were changed. I knew that scientific knowledge is absolute, and it is affected from creativity. Every week I learned different things and I was surprised.

PST #24: I took some laboratory course before, this laboratory course was different from others, because we did activities, and learned NOS very effectively. My views changed about science, I prepared lesson plans for other course, and I used some activities to teach NOS aspects. During the course after the activities there were presentations about that week aspect, I think they were very helpful for us.

PST #27: Every week we focused one aspect, and my views about NOS were changed. I understand the relation between theory and law, scientists are not objective, scientific knowledge is theory-laden and it is tentativeness. Before this course, I thought scientists right 100 % of their work, and scientific knowledge absolute and not changeable.

PST #3: Actually, I liked this laboratory course. I think NOS can be taught in laboratory better. I prefer laboratory to teach NOS. Because of students can learn doing and seeing. For example, I learned NOS in this course, and I used my NOS views for other courses. I took same laboratory courses before, we only observed something and we go out without doing anything, thus we did not learn anything. Before this course I did not know anything about NOS. I think students firstly may learn NOS then learn other science context. We separated science from society, we learned in the past only scientists do science. However, today science affects every people daily life, and firstly students should learn NOS. Thus, learning NOS directly related to scientific literacy. After this course, my views about scientific knowledge completely changed.

PST #34: Firstly, I understand NOS in this semester. I think NOS is complex, my views about NOS were changed. Sometimes only listening or reading is not enough to understand, thus I prefer laboratory activities to teach NOS. My old readings about NOS aspects were meaningful in this laboratory course. Unfortunately, up this time, I went to best schools but I had many misconceptions about nature of science. Now, I changed my views thus I am happy. In the laboratory there were some discussions, these were important I learned many things. Every week we wrote reflection papers about NOS and SPS, I think these papers helped us to understand NOS and SPS concepts. This course was the best laboratory course for me and I know for many friends. I will be a science teacher I will use these activities.

In order to analyze PSTs' perspectives and experiences related to their understandings in the course the NVivo software program was used. At the end of the analysis, three main factors were determined as provide to PSTs to develop their understandings. These are (1) importance of discussion and presentation (explicit discourse about NOS), (2) the importance of using SPS (inquiry skills), and (3) the importance of doing activities (constructivist). The Laboratory Application in science II course included these characteristics. The course was designed and introduced according to these factors.

Table 4.18. Factors affected development of NOS

Factors	n (% of N)
The Importance of Discussion and Presentation	10 (22,3 %)
The Importance of Using SPS	45 (100 %)
The Importance of Doing Activities	45 (100 %)

In the Table 4.18, n refers to number of PSTs and N refers to the sample of interviews. According to the table, 10 (22,3 %) the PSTs expressed the importance of discussion and presentation to understand NOS aspects during the intervention. For example:

PST #20: After activities, the instructor made presentation and we discussed about NOS views, thus we understood easily.

Part #34: Before this semester, I had some misconceptions, such as theories become laws, and laws cannot be changed. At the end of the activity, there was a presentation in the laboratory, we discussed these concepts, and our misconceptions were changed.

PST #4: During the activities, we discussed our group members, and at the end, we reached scientific knowledge. In addition, there were presentations after the activities, we learned and connect NOS aspects with these activities.

According to Table 4.18, all of the PSTs (45) articulated that through the semester using SPS helped to develop understanding of NOS aspects. Below, there are three statements from interviews:

PST #2: I think there are relationships among NOS, SPS and scientific knowledge. While doing experiment we use SPS, using SPS help us to study more systematic, it would be different methods in science. We can reach some results with different methods. We used SPS doing activities in laboratory.

PST #27: There is strong relationship among scientific knowledge, SPS, and NOS. I figure out that there is a destination we want to reach it, this is scientific knowledge, we used some tools which are SPS and scientific methods, and our way of this journey is NOS.

PST #6: We cannot separate NOS and SPS. Because, in order to do activity we used many SPS in laboratory, and at the end we constructed our scientific knowledge. We should do these to develop science, and findings should be shared by other peoples to develop science.

Lastly, all of the PSTs (45) stated that doing activity has an important role to develop understandings of NOS aspects. For example:

PST #31: I think laboratory is more suitable to learn not only NOS aspects but also other science context. Because in laboratory we are active, we do, thus we learn better than traditional class presentations.

PST #37: Firstly, I liked this course, I read laboratory manual before and we did activities ourselves, thus we could easily understand NOS aspects.

PST #40: I think student do not understand NOS aspect in class by direct teaching. I remember all of things in the laboratory, because first, we were in conflict then we do activities and we understood. In

> addition, until the laboratory course I did not set up any experiment, in this course we designed experiments.

4.2.2 Relevance to future teaching

After the analysis of interviews, it was found that 37 (82,3 %) preservice science teachers gained some views about their future science and NOS teaching. Although there was not any aim for this subject while planning and conducting this study, the PSTs extended their views about teaching positively. Below, there are some statements from interviews:

> Part #12: I do not think NOS can be taught in class with only lecture. Especially in elementary school, students cannot understand NOS views without laboratory. I think laboratory is important for science courses. I prefer laboratory to teach NOS aspects. Students should do experiments, they should observe directly. My views about NOS were changed during the laboratory course, if I did not join this course, I will graduated from university, I will be a teacher and unfortunately I will teach to my students wrong things about NOS.

> PST #17: When I will be a teacher, I will use laboratory for teaching NOS aspects. Because, I think elementary students could not understand NOS aspect with oral conservations. Students need activities about NOS. In this course, we did activities and we learned better, also we will be teachers, and we will teach NOS like that.

> PST #19: This laboratory is different other laboratory courses. I think not only NOS but also other science classes should be taught in laboratory. I remember when I was a high school, only I memorized scientific knowledge in class during lectures, them I forgot them. I learn better in laboratory, because I observe, and I do experiments. I will use some activities from this course, when I will be science teacher.

> PST #25: This laboratory course was different other laboratories. I think for teaching many aspects laboratory environment is useful, because students can learner better doing activities. However, some of them can be taught in class. I think laboratory should be fruitful, students should like laboratory

environments. I will use similar activities to teach NOS aspect for my students in future.

PST #29: I prefer laboratory environment to teach NOS aspects. I think if students do something they can learn better. Science classes should be student centered, students should observe, thus they like science, otherwise science classes are boring for students. Moreover, during activities students can use and develop their creativities.

PST #7: I absolutely believe that application is very important in science, because after practice scientific knowledge will be more lasting and fruitful for students. I think science lesson should be taught with inquiry methods in laboratory. Students should do experiments. If students do experiment, they can learn better. Lecture is not enough for learning, because students memorize after lecture.

PST #8: I do not think class is suitable for science education, I prefer laboratory. Because in class we listen to teachers, take note, and memorize scientific knowledge, after exams we forget all of them. Especially, NOS should be taught in laboratory, because in laboratory, students do experiment, and they can have concrete data, thus they can learn better.

In these quotations, PSTs emphasized that when they will be science teachers, they will prefer to use inquiry-based laboratory activities to teach NOS aspect and other science concepts. The PSTs compared their past learning at middle or high school and they stated difference between inquiry learning and memorizing. Generally, they memorized science concepts during their education, but they realized they did not learn. They accepted that science concepts should be thought in laboratory environment using scientific activities. They had a common point that was students learn better doing inquiry-based laboratory activities.

4.3 Summary of the finding chapter

According to data analysis, PSTs associated the specific laboratory activities with specific NOS aspects. In addition, many of the PSTs stated more adequate views about NOS at the end of the semester. Moreover, the PSTs correlated NOS aspects wisely at the end of the course. Data analysis showed that, there are three factors, which affected PSTs' understandings of NOS views. These are discussions and presentations, using inquiry skills, and doing inquiry-based laboratory activities. Furthermore, PST gained useful experiences about their future professional science teaching.

CHAPTER 5

DISCUSSION

This chapter provides a discussion of the findings of this research. The purpose of this study was to explore the understandings of PSTs' NOS aspects during the explicit-reflective and inquiry-based laboratory instruction. While previous studies have explored the effectiveness of the explicit and implicit way of teaching NOS, little is known about the effectiveness of the explicit instruction when applied in different instructional contexts other than method courses (Lederman, 2007). Thus, this study has the potential to contribute to the NOS literature by investigating the explicit-reflective instruction applied in the context of an inquiry-based laboratory course for PSTs.

Two major research questions guided to this study. Each will be discussed respectively in the sections that follow.

5.1 Research Question 1;

To what extend does the explicit and reflective approach, when implemented in the context of inquiry-based laboratory instruction, impact preservice science teachers' views of NOS?

This research question was examined under three sub-questions in the findings chapter. (1) Do PSTs associate the inquiry-based laboratory activities with the aspects of NOS? This sub-question sought the connections that PSTs made between the laboratory activities and the targeted NOS aspects. (2) How do PSTs' views change as a result of participating in these laboratory activities? This sub-question focused on developments in PSTs' views of NOS, both in aggregate terms as well as by examining changes in individual PSTs' understanding. (3) Do PSTs link among the separate aspects of NOS? This sub-question determined connections that PSTs made among various aspects of NOS.

5.1.1 Do PSTs associate the inquiry-based laboratory activities with the aspects of NOS?

For the first sub question, it was found that all of the PSTs were able to make appropriate connections between the laboratory activities and the targeted NOS aspects. Furthermore, PSTs expressed that each activity is suitable to understand and develop understanding of the targeted NOS aspect properly. This finding provides evidence for the effectiveness of the design of the intervention activities in targeting specific aspects of NOS. Although many PSTs took a method course during the same semester, only five of the PSTs mentioned the effectiveness of the method course to understand NOS aspects. Since the PSTs made specific references to ways in which the inquiry-based laboratory activities helped change their views of NOS. It can be inferred that the PSTs' NOS understandings were improved during the laboratory course.

Other researchers used a similar approach, the explicit-reflective and activity-based instruction to enhance preservice elementary teachers' views of NOS. Akerson, Abd-El-Khalick, and Lederman (2000) used a set of activities to develop preservice elementary teachers' NOS views. They found this approach was effective to develop participants' understandings of some NOS aspects, not all of the NOS aspects. In addition, many researchers used the explicit-reflective approach and content-generic activities in science method courses (Lederman & Abd-El-Khalick, 1998). Science literature showed that some studies to enhance teachers' NOS understanding had only limited success (Akerson & Hanuscin, 2003). It was not possible to teach all NOS aspects effectively, because the nature and long agenda of pedagogy courses. Educators stressed a lack of emphasis on NOS across prospective teachers' programs as a reason for this limited achievement and stated that teaching NOS should engage in not only pedagogy courses but also science content courses (Abd-El-Khalick & Lederman, 2000).

Some researchers focused on science content courses to enhance learners' understanding of NOS. For example, Brickhouse, Dagher, Letts, and Shipman (2000) stated, "studying students' views about the nature of science is best done in a context where it is possible to talk about particular theories or particular pieces of evidence" (p. 355). While designing the present study, the explicit-reflective approach was considered, and science concepts were integrated. Thus, this study is different from other attempts in terms of activities and the intervention. It was applied in science the laboratory class and activities were designed for inquiry approach, minds on together with hands on; also, activities included content-embedded parts. The results of this study consistent with studies that propose that students' NOS views may be context dependent (Hanuscin, Akerson, & Phillipson-Mower, 2006; Sandoval &Morrison, 2003).

Similar findings in which participants referenced the intervention activities in their explanations of their views of NOS were found by Hanuscin, Akerson, and Phillipson-Mower (2006). This study and the present study focused on content-embedded laboratory activities. In both of the studies, participants gained substantial insights about the target NOS aspects.

The constructivist approach was based in the present study, according to this approach, learners' experiences affect their cognitive structures, and scientific knowledge is constructed when individuals engage socially in discussions about shared problems or tasks. It can be stated that, after engagement in the explicit-reflective and inquiry-based laboratory activities PSTs constructed their understanding of NOS aspects. According to results, PSTs attributed their understandings to the using science process skills and doing inquiry-based activities. Moreover, they pointed out the importance of discussions held in small groups and between whole groups during the laboratory activities.

5.1.2 How do PSTs' views change as a result of participating in these laboratory activities?

The second sub-question includes PSTs' developments of NOS aspects. At the beginning, many of the PSTs held NOS views, which are described as 'inconsistent' with science reforms similar to past studies (Lederman, 1992). However, at the end of the study, post data results showed that many of the PSTs furthered their understanding for many aspects of NOS. Moreover, as a group, the PSTs' number of statements that were aligned with contemporary views of NOS increased for all aspects at the end of the course. More results are presented for separate NOS aspects below.

5.1.2.1 The Empirical Nature of Scientific Knowledge

According to the findings, there are developments of PSTs' understanding of empirical basis and its subcategories. PSTs articulated that knowledge in science relies on evidence rather than authority. They expressed that there should be some processes to reach scientific knowledge. During these processes, hypotheses can be tested and scientific knowledge can be reached. This knowledge is rational not dogmatic. In addition, PSTs emphasized that in order to build scientific knowledge we need data and evidence, and we can gain these by doing experiments and observations. Moreover, they focused on the fact that scientific knowledge should be reliable and to support reliability were needed. Lastly, they stated that doing experiments could promote the show of cause-effect relationships for scientific knowledge. These findings are similar to previous studies, which showed that preservice teachers articulated more sufficient views about the empirical NOS (Akerson, Abd-El-Khalick, & Lederman, 2000).

The intervention was begun with the empirical basis of NOS, because the researcher thought PSTs would be most familiar with the idea of evidence, versus other aspects such as the socio-cultural embeddedness of science. It was expected that some students would hold the idea that evidence could be used to "prove" scientific ideas. At the beginning, the researcher anticipated that such ideas would change by the end of the semester.

No development was found for some of the PSTs (19 out of 45) about their empirical basis of NOS views. One of them has consistent views, 13 have transitional views, and five have inconsistent views with the current reforms. These PSTs did not change their conceptual understanding during the laboratory activities, because they were familiar with the acquisition of scientific knowledge by means of experiments from their educational life. This situation can be explained by lack of first condition of conceptual change model. According to the model (Posner, Strike, Hewson, & Gertzog, 1982), if learners meet a new situation, it causes condition of dissatisfaction. However, some of the PSTs were not confronted with a new situation. Clough (2006) applied Appleton's (1993) constructivist model of learning in science to consider learners' responses to the demands of conceptual change with specific regarding to understanding NOS. This model emphasizes that while learners would ideally exit from instruction only after their deep cognitive effort resulted in understandings that are both consistent with their learning experiences and congruent with accepted scientific knowledge. Learners may exit prematurely from instruction possessing what appears to be an idea that fits with their existing knowledge, but does not conform to scientifically accepted views. When this occurs, "pre-existing NOS ideas have not been abandoned, only slightly modified or left intact with new schema created that are disconnected from the larger conceptual framework" (2006, p. 470). Clough (2006) suggested that students think their ideas match the new situations; therefore, they do not change their previous ideas.

In Turkey, previous studies showed that preservice science teachers held some inconsistent views about empirical based on NOS. For instance; “[PST] believed that scientific knowledge should be proven true based on objective observation or experimental evidences” (Erdogan, Cakiroglu, & Tekkaya, 2006, p. 282). Similarly, another study determined this negative condition about empirical basis of NOS for Turkish preservice science teachers (Liang, Chen, Chen, Kaya, Adams, Macklin, & Ebenezer, 2009). However, the present study showed that many (25) PSTs develop their views about the empirical NOS aspect at the end of the semester. It can be concluded that, the explicit-reflective and inquiry-based laboratory instruction had an effect on PSTs to enhance their understanding about empirical NOS aspect.

5.1.2.2 Distinction between Observation and Inference

At the end of the course, PSTs developed their understandings about observations and inferences. The PSTs expressed that observations and inferences are different. Both of them are important for generating scientific knowledge. According to data analyses, this aspect included five subcategories, these are; (1) Observation for experimental evidences; (2) Inference for models in science; (3) Observation and inference are different; (4) Scientific knowledge is inferred; and (5) Scientific knowledge is observed. Compared with these subcategories according to pre and post results, PSTs elucidated adequate views of these categories at the end of the study. Especially, while answering the question from VNOS-B about how modern atom structure is decided, PSTs enhanced their understandings about the importance of models in science and inferential scientific knowledge. Previous research showed that some teachers naively believed that scientists should make the same inferences and observations from the same phenomena, because scientists are objective (McComas, 1998). The study revealed that, in the sample many (31%) of the Turkish preservice science teachers hold inconsistent views, which scientist might have different interpretations, but they would make the same observations because observations were facts (Liang, Chen, Chen, Kaya, Adams, Macklin, & Ebenezer, 2009).

At the end of the intervention, approximately 83% of PSTs showed developments about this NOS aspect, it can be stated that the Black Box activity is an effective way to enhance PSTs' NOS views, while conducting together the explicit-reflective instruction in laboratory.

5.1.2.3 The Relationships between Scientific Theories and Laws

According to findings, PSTs developed their understandings about theories and laws. They expressed that theories and laws are different kinds of scientific knowledge and a theory does not mature a law. However, at the beginning PSTs hold some similar naïve views with previous studies about this NOS aspect. A recent study revealed that in the sample many (95%) of the Turkish preservice science teachers stated laws are proven by theories (Liang, Chen, Chen, Kaya, Adams, Macklin, & Ebenezer, 2009). Another study in Turkey, showed that preservice science teachers proposed that laws contain upper status than theories, and they did not realize theories do not mature laws (Erdogan, Cakiroglu, & Tekkaya, 2006). In the present study, many of the PSTs explicated inadequate views of this NOS aspect at the beginning the intervention. They had some common misconceptions consistent with previous findings such as there are hierarchical steps among hypothesis, theories, and laws (e.g., Hanuscin, Phillipson-Mower, & Akerson, 2006; McComas & Olson, 1998). Moreover, many PSTs hold another misconception, which laws cannot be changed and they are universal. Furthermore, some PSTs mentioned about science teachers as sources of these misunderstandings. It can be concluded that science teachers have an important role to construct students' understandings of NOS aspects. In addition, PSTs stated that high schools science books include some misconceptions about theories and laws. This result consistent with a previous study, which was conducted by Yalvac, Tekkaya, Cakiroglu, and Kahyaoglu (2007), the researchers criticized high school textbooks and they find out there was an unit in a textbooks, which include the hierarchical situation among hypothesis, theories, and laws.

Sandoval and Morrison (2003) studied on high school students' views about theories and theory change as one of the NOS aspects. They focused on the role of inquiry experiences for development aspect of NOS. They did not find any development and they emphasized the importance of explicit instruction. The current study applied not only inquiry-based but also explicit-reflective instruction.

At the conclusion of the present study, many of the PSTs declared views that are more adequate; there is no hierarchical relationship between theories and laws, they are different kinds of scientific knowledge, and theories try to explain laws. During the activity in laboratory, PSTs studied on a law (a phenomenon) and some theories to explain this phenomenon. At the end, they recognized theories and laws are different types of scientific knowledge and one does not develop into other.

5.1.2.4 The Subjectivity of Scientific Knowledge

The results showed that many PSTs hold inconsistent views about subjectivity at the beginning of the semester. After the course, except six PSTs, all of them developed their understandings and they dedicated some reasons as factors for subjectivity of scientific knowledge. PSTs recognized that scientists' creativities and imaginations, educational backgrounds, personal references, and using existing theories can affect scientific studies. The gains in the understandings of this NOS aspect achieved by PSTs could be attributed to engagement in the laboratory activity. In this study, there was a specific activity for subjectivity; it was related to existing theories. After the activity, PSTs understood the effects of existing theories on scientific investigations. Moreover, they concluded that scientists are affected theories during scientific research, this cause subjectivity in science. Therefore, scientific knowledge is theory-laden. In addition, their perspectives toward science were changed from objective to subjective perspective.

In their study, Akerson, Abd-El-Khalick, and Lederman (2000) concluded that participants completed relatively less substantial gains in understanding of subjectivity. During their intervention, the researchers shared a few brief examples from history of science, thus they stated that this was not enough to develop participants' NOS views about subjectivity. In the present study, the PSTs did the activity, at the end they discussed and shared their findings. Therefore, PSTs develop consistent views about subjectivity, at the end of the explicit-reflective and inquiry based laboratory instruction.

5.1.2.5 The Tentative Nature of Scientific Knowledge

At the end of the semester, prospective science teachers developed their understandings about tentativeness of scientific knowledge. The PSTs realized a characteristic of scientific knowledge it is subject to change. Many PSTs expressed that scientific knowledge is not absolute or certain knowledge in science.

The PSTs stated that the changes were done by means of technologic developments and new evidences. This finding is consistent with the results in literature, many preservice teachers hold informed views about tentative nature of science, but participants proposed new technology is the only reason for tentativeness (Akerson, Abd-El-Khalick, & Lederman, 2000; Liang, Chen, Chen, Kaya, Adams, Macklin, & Ebenezer, 2009).

On the other hand, in the current study, the PSTs stated that new interpretations could change existing scientific knowledge, after the activity. Moreover, some PSTs focused on the role of tentativeness to develop scientific knowledge, this is important because PSTs understood the main idea under the tentativeness, it promotes scientific development, it is not failure of scientific knowledge. Furthermore, at the end of the semester, PSTs changed their views about truth of scientific knowledge; they linked this aspect to school modern science concepts.

5.1.2.6 The Role of Creativity and Imagination in Generating Scientific Knowledge

According to findings, PSTs stressed the importance of creativity and imagination for scientific knowledge at the end of the semester. In accordance with literature, preservice science teachers in Turkey hold inconsistent views about this NOS aspect, they expressed that scientists do not use their creativities and imagination in generating scientific knowledge (Erdogan, Cakiroglu, & Tekkaya, 2006; Liang, Chen, Chen, Kaya, Adams, Macklin, & Ebenezer, 2009). On the other hand, the PSTs in this study emphasized that especially scientists use their creativities and imaginations during their scientific investigations. Therefore, creativity and imagination affect scientific knowledge. Moreover, PSTs discussed some possible reasons for different creativity and imagination. For example, culture and religion may affect scientist' creativity, thus it can be related to subjectivity of scientific knowledge. Although some PSTs stated scientists do not use creativity and imagination or partially use creativity and imagination at the outset of the semester, they elucidated more views that are adequate after the course. Furthermore, after the specific activity PSTs perception about 'scientists' was changed, they realized that scientists are normal people like others, they are not superman. Similar result was found by Morrison, Raab, and Ingram (2009), who conducted a study in an authentic research environment and teachers had a chance to interact with scientists on an informal level. The researchers gave an opportunity for teachers to observe, discuss, and have time to talk about science with scientists. After their study, elementary science teachers stated that "they [scientist] are people just like me" (p. 399), the present study showed similar result without any interaction between scientist and PSTs. Therefore, it can be concluded that the specific activity had an important effect to develop PSTs' views. These findings showed that a suitable inquiry-based laboratory activity could promote more development about the NOS aspect in limited time.

5.1.2.7 The Role of Socio-Cultural Effects in Generating Scientific Knowledge

The results showed that many PSTs realized that social factors affect development of scientific knowledge. Some research revealed that preservice science teachers in Turkey did not demonstrate informed understanding of the role of social and cultural factors for scientific knowledge (Erdogan, Cakiroglu, & Tekkaya, 2006; Liang, Chen, Chen, Kaya, Adams, Macklin, & Ebenezer, 2009). In addition, researchers used some historical examples to improve this NOS aspect; however, studies showed that developing this NOS aspect is not straightforward for preservice science teachers (Akerson, Abd-El-Khalick, & Lederman, 2000).

In the current study, the inquiry-based laboratory activity was utilized, and the groups in the laboratory were assigned as different cultures. The PSTs demonstrated adequate views for the social and cultural aspect of NOS at the end of the course. They emphasized that society and culture can affect science. They discussed that science is constructed by scientists in society, and they proposed that science and society could not be separate from each other.

5.1.3 Do PSTs link among the separate aspects of NOS?

As an answer to the third sub-question of the first research question, the findings showed that some of the PSTs made connections between NOS aspects and generally, these connections were made at the end of the semester. Some researchers claim that individual aspects of NOS by themselves do not represent the nature of science. It is not easy to describe specific NOS aspects as being distinct from one another. For instance, according to Osborne, Collins, Ratcliffe, Millar, and Duschl (2003) some of the NOS aspects are intertwined and they cannot be separated from each other. They found that "[…] many of the aspects of the nature of science […] have features that are interrelated and cannot be taught independently of each other." (p.712). Schwartz and Lederman (2002) suggested that connections promote understanding of NOS aspects in a more adequate way. In the present study, results showed that, PSTs develop their understandings of NOS aspects, at the same time they linked NOS aspects after the intervention.

It is important to note that, while designing the study the researcher did not concern this issue, thus each NOS aspect was targeted separately. However, during the data analyses, these connections were realized. Every week there were discussion parts at the end of the activities, and PSTs reflected their ideas about the connections of NOS aspects. The instructors did not impede the PSTs ideas and they did not guide about these connections. This might help to explain why PSTs made these connections among NOS aspects. In addition, the reason for these connections can be explained as using explicit-reflective and inquiry-based laboratory instruction.

5.1.4 Summary

Three basic assertions can be made from the findings in relation to the first research question. Firstly, PSTs associated the inquiry-based laboratory activities and the targeted NOS aspects. Second, the explicit-reflective instruction is effective to improve NOS aspects, when implemented in the context of inquiry-based laboratory instruction. Lastly, some aspects of NOS were connected by PSTs at the end of the semester.

The findings from this study demonstrate that the inquiry-based laboratory activities are related to the NOS aspects. While many studies have examined NOS instruction in the context of methods courses (e.g., Abd-El-Khalick & Akerson, 2004), this particular study focused on a laboratory science course. The PSTs in the course engaged in inquiry-based laboratory investigations, and data indicate that they viewed a strong association between their own activities and the activities of science. That is, they were able to make important connections between their own knowledge building in class with the knowledge building practices of scientists.

The findings further illustrate that explicit-reflective instruction is effective in the context of inquiry-based laboratory instruction. On the other hand, Khishfe and Abd-El-Khalick (2002) compared an implicit inquiry-oriented approach and an explicit and reflective inquiry-oriented approach, and they concluded the explicit-reflective and inquiry-oriented approach is more effective than former approach. Moreover, they expressed that "…inquiry by itself seems insufficient to teach students about NOS" (p. 574). As the authors mentioned that inquiry approach has not any direct role to understand NOS aspects, however, inquiry approach supports to learners to construct their understanding. Therefore, using these approaches with explicit-reflective method is wisely and it promotes to permanence for understandings.

It can be concluded that the inquiry-based laboratory activities used in this study were related to specific NOS aspects and they encouraged to development understandings. In addition, the explicit-reflective teaching provided more opportunities for PSTs to understand contemporary views and change their naïve views. Furthermore, PSTs correlated NOS aspects wisely after the intervention.

5.2 Research Question 2;

What are preservice science teachers' perspectives and experiences related to their learning in the science laboratory course?

This research question was examined under two sub-questions in the findings chapter. (1) What are preservice science teachers' perspectives about factors that might affect their understanding of NOS aspects? This sub-question sought students' thoughts for possible factors their developments of NOS views. (2) What are preservice science teachers' perspectives about future science teaching? Second sub-question focused on PSTs' views about their professional teaching.

5.2.1 What are preservice science teachers' perspectives about factors that might affect their understanding of NOS aspects?

The results showed that PSTs develop their understandings of NOS aspects at the end of the laboratory course. According to the results, PSTs stated three factors, which have role to develop their NOS understandings. These are the importance of discussion and presentation, the importance of SPS, and the importance of doing inquiry-based laboratory activities. The difference between SPS and inquiry was determined by the Standards (NRC, 1996) as "Inquiry is a step beyond 'science as a process,' in which students learn skills, such as observation, inference, and experimentation. The new vision includes the 'process of science' and requires that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science." (p. 15).

As a first factor, PSTs emphasized the importance of discussions and presentations at the end of the laboratory activities. The laboratory course was designed and the inquiry-based activities were prepared according to explicit-reflective teaching approach. Following the inquiry-based laboratory activities, there were power-point presentations to reflect science educators' NOS views. Generally, these presentations were summaries for the readings parts. After that, PSTs were engaged in reflective discussions of the target NOS aspects, they shared and discussed their results. Reflective discussions of the target NOS aspects are important, Khishfe and Abd-El-Khalick (2002) conducted an experimental research, and they showed effectiveness of discussions after inquiry-based activities on behalf of experimental group.

As a second factor, all of the PSTs stated the importance of using science process skills (SPS) helped to develop understanding of NOS aspects. The relation between science process skills and NOS should be made clear, both are important for students to learn science. On the one hand, scientific processes are skills related to doing experiments, such as observation and inference. On the other hand, NOS refers to the epistemological promises. Bell, Lederman, and Abd-El-Khalick (2000) stated, "[A]n understanding that observations are constrained by our perceptual apparatus and are inherently theory-laden is part of an understanding of the nature of science" (p. 565).

In the past, researchers utilized SPS to develop NOS understanding. These attempts were classified as examples of the implicit approach (Abd-El-Khalick & Lederman, 2000). Especially, many of the 1960s and 1970s education programs SPS were accepted an important tool to enhance students' understandings of NOS views. However, most of the studies failed to develop students' NOS views (Gabel, Rubba, & Franz, 1977; Lawson, 1982; Rowe, 1974). For the reason that, the implicit approach assumed that NOS understanding is an 'affective' learning outcome not 'cognitive' (Abd-El-Khalick & Lederman, 2000). Therefore, they did not realize that, in order to improve NOS understanding it needs instructions, which included intentionally and planned NOS aspects.

On the other hand, in this study SPS formed as an important part of explicit-reflective and inquiry-based laboratory activities. While preparing activity sheets many times SPS were used as headings, such as 'construct your hypotheses and 'define your variables' for activities. PSTs expressed that SPS helped us to study more systematic, to conclude activities, and to reach scientific knowledge. There are strong relationships among some NOS aspects and some SPS (Khishfe & Abd-El-Khalick, 2002). Researchers noted that, students often conflate SPS with NOS aspects and it is necessary to distinguish both of them (Abd-El-Khalick, Bell, & Lederman, 1998). In this study, these relationships were constructed by PSTs at the end of the course. For instance, observation is one of the important science process skills, also observation is an important way to gain information about natural phenomena, and it is differ from inference. PSTs used their SPS and they improve their understandings of NOS aspects.

As a third factor, all of the PSTs indicated the importance of doing inquiry-based laboratory activities for understandings of NOS aspects. Using inquiry-based activities was classified as a tool for implicit approach (Abd-El-Khalick & Lederman, 2000). However, in this study inquiry-based laboratory activities and explicit-reflective teaching were integrated. Indeed, according to Inquiry and the National Science Education Standards (NRC, 2000), inquiry-based learning has three dimensions for students. These are learning science concepts and principles, gaining some skills to conduct scientific investigation, and understanding of nature of science. Therefore, using inquiry-based laboratory activities in order to develop NOS views is practical. For example, Schwartz, Lederman, and Abd-El-Khalick (2000) expressed that “For science classroom, explicit instruction attention to, and reflection on nature of science, perhaps in conjunction with, and in direct reference to inquiry activities in which the students are engaged may be the critical pedagogical component required for successful teaching of nature of science through inquiry” (p. 8). In the same way, Abd-El-Khalick and Lederman, (2000) stated that “involving learners in science-based inquiry activities can be more of an explicit approach if the learners were provided with opportunities to reflect on their experiences from within a conceptual framework that explicates some aspects of NOS." (p. 689).

According to reviews about NOS (Abd-El-Khalick & Lederman, 2000; Lederman, 1992; Lederman, 2007) researchers, who believed that developing of NOS views as 'cognitive' learning outcome, and they used explicit approach. Explicit-reflective approach differs from didactic teaching, and this approach emphasized understandings of NOS are cognitive outcome, therefore NOS should be purposively taught (Khishfe & Abd-El-Khalick, 2002). In this study, NOS aspects were targeted and planned intentionally. In addition, constructivist approach was considered, because this approach helps PSTs construct their understandings of NOS aspects. NOS understandings are cognitive learning outcomes, and they could be best taught using explicit-reflective way as a constructivist approach.

5.2.2 What are preservice science teachers' perspectives about future science teaching?

Many research efforts aimed to develop adequate conceptions of NOS for students (Lederman, 2007). Especially some of them focused on teachers' conceptions and their practices in classrooms about NOS (Lederman, 1992). Researchers accepted three assumptions about students' understandings of NOS conceptions in classroom. These are; students' conceptions were significantly related to their teachers' conceptions, teachers transform their conceptions into their practice, and students can gain implicitly adequate NOS views doing inquiry-based activities (Abd-El-Khalick, Bell, & Lederman, 1998). After the research about this topic Abd-El-Khalick, Bell, and Lederman, (1998) concluded that teachers' conceptions of NOS and their practices in classrooms is more complex. In addition, they indicated that teachers' beliefs about NOS do not automatically influence their practices in classrooms (Abd-El-Khalick, Bell, & Lederman, 1998).

In the findings chapter, aforementioned that there was not any goal about PSTs' future teaching while planning and conducting this study. However, at the end of the course PSTs extended their views about teaching NOS positively. PSTs expressed, they will translate their NOS conceptions in their classrooms, and they will prefer to use explicit reflective and inquiry-based laboratory activities to teach NOS aspect. Laboratory Application in Science II course did not include any part related to planning and practicing NOS aspects for PSTs. Therefore, there was not any opportunity to asses PSTs' practices about teaching NOS aspects. Further research should explore the effectiveness of NOS instruction on PSTs by examining their real classroom practices.

5.3 Implications

Science teachers have an important role in the implementation of the curriculum reforms of science classes (Abd-El-Khalick, Bell, &Lederman, 1998). For this reason, teachers should develop informed views about NOS, and they should translate their understanding into science classes (Lederman, 2007). However, according to literature, science teachers do not have informed views about NOS (Lederman, 1992; 2007). For instance, preservice science teachers accepted science as "a process of discovering what is out there, not as a human process of inventing explanations that work" (Abell & Smith, 1994, p. 484). Therefore, it is vital that be given consideration to PSTs' conceptual understandings of NOS. While planning some courses, which are related to training preservice teachers, NOS views should be integrated consciously (Akerson, Abd-El-Khalick, & Lederman, 2000). The results of this study propose that this can be accomplished by means of planning the explicit-reflective and inquiry-based laboratory instructions.

According to science education reforms, students should have adequate views about characteristics of scientific knowledge regardless of cultures (NRC, 1996; MoNE, 2005). This study was conducted in Turkey. Developing of contemporary NOS views has an important part in the newly developed science education curriculum that aims to develop scientifically literate persons in Turkey (Liang, Chen, Chen, Kaya, Adams, Macklin, & Ebenezer, 2009; MoNE, 2005; Yalvac, Tekkaya, Cakiroglu, & Kahyaoglu, 2007).

Science curriculums in elementary and high schools in Turkey were content based before 2001. They included too many science concepts, and teachers had to choose traditional teaching methods to complete all topics during semesters (Simsek & Yildirim, 2001). Recent reform movements affected the Turkish education system, and the teacher education program was redesigned and the new program promoted especially field experiences, scientific literacy, and contemporary teaching methods (MoNE, 2005).

After the newly developed science curricula, the central goal of science education as teaching facts and theories changed. In addition, student-centered teaching methods were suggested. However, some national exams constituted a problem in the Turkish education system, because students were encouraged to master the science content knowledge. Students were expected to get high scores for high school and university entrance examinations. These exams require more content knowledge (Yalvac, Tekkaya, Cakiroglu & Kahyaoglu, 2007). For this reason, it is difficult to attain a central objective about NOS for the recent science education curricula. Therefore, science teachers focused on such subject knowledge as chemistry, physics, biology, math, and Turkish. The other aspects related to NOS, STS, and environment education parts were neglected (Cimer, 2004).

At the outset of the current study, many PSTs hold some inconsistent views about NOS aspects. Some reasons can be proposed to explain this implausible result. One of them is related to students' school experiences with respect to previous science learning. In this study, PSTs' understandings about science were developed before the 2001 reforms in their elementary education. Although, they were in high schools when the new science curriculum was developed, they had to focus more on science concepts and to get high scores to enter the university. During their elementary, middle, and high school education preservice teachers were taught using traditional teaching strategies (Yalvac, Tekkaya, Cakiroglu & Kahyaoglu, 2007). These strategies did not promote contemporary views about science. Students were expected to memorize more content knowledge and to get high scores from national exams (Yalvac, Tekkaya, Cakiroglu & Kahyaoglu, 2007). The other reason is related to science textbooks; unfortunately, some old textbooks had misleading assumptions about NOS (Erdogan, Cakiroglu, & Tekkaya, 2006). Therefore, our PSTs' views about NOS were developed during their 13-year education life. In addition, as a result of their school experiences, they hold some inadequate conceptions about NOS at the beginning of the semester. After the entering to the university, in the first two years, they took content-based courses and laboratories. After the explicit-reflective and inquiry-based laboratory instruction, many PSTs develop and changed inconsistent views about NOS. It can be concluded that this type of instruction can improve preservice science teachers' understanding of NOS views.

In the light of these findings, it can be concluded that in order to achieve new designed science curriculum objectives about NOS, the first step is to educate preservice science teachers. Because they will be science teachers and they will have opportunities to provide suitable classroom environment for their students to understand NOS aspects properly.

Teacher education programs and teacher educators in education faculties have a mission to train science teachers, who understand NOS properly and they have essential skills to implement NOS views into their future science classrooms. In addition, teacher preparation programs should be revised according to current reform. By doing so, some new courses related to teaching NOS can be developed or the existing ones can be reviewed. Science teacher educators should integrate NOS aspects and their teachings into their courses. Moreover, science teacher educators should give opportunities for prospective science teachers to reflect and practice their learning about NOS. Many science teacher educators used their method courses to improve NOS views. With this, they should be aware of other opportunities to develop students' understandings about NOS.

Science teacher training programs were accepted as last opportunity to change traditional NOS views (Abd-El-Khalick & Lederman, 2000). Because science teachers are indispensable factor to improve students' NOS views, some curses should be provided that include NOS aspects (Irez, 2006). This study can be one of the ways to train preservice science teachers for science teacher educators and it gives some examples about laboratory activities for elementary science teachers.

According to Erdogan, Cakiroglu, and Tekkaya (2006), preservice science teachers in Turkey did not have an adequate understanding of NOS. The authors stressed the lack of emphasis on NOS in science related courses in teacher training programs, and they suggested using the explicit-reflection based approach. In addition, they recommended that developing science content courses and method courses to improve preservice science teachers' understanding of NOS views. The researchers concluded that most of the preservice science teachers complete from their teacher education program with some traditional views of NOS, and they requested that ways to facilitate preservice science teachers' understanding of NOS be found (Erdogan, Cakiroglu, & Tekkaya, 2006). In the present study, the science laboratory course was redesigned and NOS views were addressed during the explicit-reflective instruction.

Lederman (2007) proposed some future directions for researchers; he emphasized some questions, which have yet to be explored in depth. First, *how do teachers' conceptions of NOS develop over time? What factors are important, and are certain factors more related to certain aspects of nature of science than others?* In this study, preservice science teachers' views on NOS were explored, and indicated that at the end of the laboratory course many of the participants develop their NOS views in different levels. This study showed that some NOS aspects, which the difference between observation and inference, the relationship between theories and laws, subjectivity and tentativeness were changed more easily than other aspects. Moreover, PSTs stated some factors are important their developments of

NOS aspects, these were joining presentation and discussions, applying science process skills, and doing inquiry-based laboratory activities.

Second, Lederman (2007) asked that *is explicit-reflective instruction in the context of a laboratory investigation more or less effective than other explicit-reflective applications.* This study was conducted in science laboratory and explicit-reflective approach was utilized. When results of the study were compared with others explicit-reflective investigation, it can be concluded that explicit-reflective instruction in laboratory has greater effect than other applications.

Third, *is the nature of science learned better by students if it is embedded within traditional subject matter or as a separate "pull-out" topic? Should the nature of science be addressed as both a separate "pull-out" as well as embedded?* In this study, NOS aspects were embedded within science subject matter such as photosynthesis and evolution. At the end PSTs develop their NOS views at the same time understanding science contexts.

For these reasons, this study can be accepted as an answer to these questions. Future studies should focus on preservice science teachers real classroom practices for teaching NOS.

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APPENDICES

APPENDIX A

Views of Nature of Science Version B (VNOS-B) Questionnaire

1. After scientists have developed a theory (e.g., the atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to teach scientific theories. Defend your answer with examples.

2. What does an atom look like? How certain are scientists about the structure of the atom? What specific evidence do you think that scientists use to determine what an atom looks like?

3. Is there a difference between a scientific theory and law? Give an example to illustrate your answer.

4. How are science and art similar? How are they different?

5. Scientists perform experiments/investigations when trying to solve problems. Other than the planning and design of these experiments/investigations, do scientists use their creativity and imagination during and after data collection? Please explain your answer and provide examples if appropriate.

6. Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer.

7. Some astronomers believe that the universe is expanding while others believe that it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?

APPENDIX B

Laboratory Activities

Name	**:**
Surname	**:**
ID Number	**:**
Section	**:**

Laboratory 1

Overview

Rationale

Major studies in science education emphasized the importance of students' understanding of nature of science and scientific inquiry (American Association for the Advancement of Science (AAAS), 1993; National Research Council (NRC), 1996; National Ministry of Education Turkey (MEB), 2004). This emphasize aimed to achieve development of scientific literacy for all students. Scientific literacy includes deep understandings of scientific concepts, the process of scientific inquiry, and the nature of science (Bell, Blair, Crawford and Lederman, 2003). It is clear that the process of scientific inquiry and the nature of science are major components of scientifically literate students.

Although science associations and science educators aim to develop conceptions of nature of science (NOS), there is no agreement upon a single definition of nature of science. One of the most famous definitions of NOS related to epistemology of science, science a way of knowing, and related to the values and beliefs inherent to the development of scientific knowledge (Abd-el-Khalick, Bell and Lederman 1998). There are some main aspects of NOS. Some of them are scientific knowledge is empirical based, tentative, subjective etc. (Schwartz, Lederman & Crawford, 2004).

Science process skills (SPS) are thinking skills that scientists use to construct knowledge, think on problems, and formulate the results (Carin, Bass, & Contant, 2005). Scientists make their discoveries by using their science process skills (Abruscato, 1995). SPS are classified in two different forms; Basic and Integrated SPS. Basic SPS consist of observing, inferring, measuring, communicating, classifying, and predicting. Integrated SPS consist of controlling variables, defining operationally, formulating hypotheses, interpreting data, experimenting, formulating models, and presenting information (Brotherton & Preece, 1995).

In this week we will focus first aspect of NOS; Empirical basis; scientific knowledge is based on evidence and observations of nature.

Objectives

At the end of the laboratory pre service teacher should be able to;

1. Explain the first aspect of NOS; Empirical basis; scientific knowledge is based on evidence and observations of nature (specific learning outcomes)

2. Use appropriate basic and integrated science process skills (specific learning outcomes)

3. Design an experiment about germination of a bean (specific learning outcomes)

4. Summarize nature and steps germination of a bean (specific learning outcomes)

5. Explain variables; affect the germination process of a bean (specific learning outcomes)

Which variables affect the rate of germination seeds?

Introduction

This laboratory experiment will provide you opportunity to understand the first NOS aspect (The Empirical Nature of Scientific Knowledge) and to use necessary basic and integrated SPS.

Preliminary Information

"Seed germination is important to the world because all the people get most of their food from plants. Even people who eat meat are dependent on plants for the animals to eat. Germination, is the sprouting of a seed. When germination begins the seed needs a lot of water. The water makes a chemical change that enables the embryo to store food and energy for growth. The water also causes the embryo to enlarge and split the seed coat. Germinating seeds require a large amount of oxygen because of their high rate of respiration. Respiration is taking in oxygen and giving off carbon dioxide. The radical then emerges and grows forming its first root.

All seeds need moisture, oxygen and warmth to germinate. If they don't have warmth the seeds will go through dormancy. That prevents seeds from germinating. Most seeds remain dormant in the winter because of weather conditions. Some seeds germinate in the summer because they need higher temperatures than others do that germinate in the spring. Most seeds require a cold period before starting germination.

All seeds have three main parts: the seed coat, the embryo and the food storage tissue. The seed coat protects the embryo and the food storage tissue from loss of water, insects and injury. The seed coat can be thin and delicate, as in wheat and beans, or thick and tough, as in a coconut. The embryo contains the part of the seed that develops into the first root, then the stem and the first leaves. The cotyledons in the seed absorb and digest the food from the food storage tissue. The cotyledons in some of the dicotyledon seeds absorb the food in the endosperm. The cotyledons then store the food in the embryo."

Materials

Bean seeds (different size), soil, plastic container, water, thermometer, and light sources, ...

Your research study should include;

1. State your group purpose

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2. State your group hypothesis

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3. Define your variables and write in the below table

	Variables	**Operational Definitions**
Manipulated		
Responding		
Controlled		

4. Determine materials you will use

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5. Write the procedure you will fallow

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6. Set up your experimental design

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7. Collect data (observation, measurement), and draw a data table (you should take data for every twelve hours)

8. Draw a graph based on your data and find the rate of germination

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9. Write your conclusion

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- Do not forget to write your references if you have.

Laboratory 1(1)

Name	**:**
Surname	**:**
ID Number	**:**
Section	**:**

Overview

Rationale

In this week we will focus first aspect of NOS; Empirical basis; scientific knowledge is based on evidence and observations of nature.

Objectives

At the end of the laboratory pre service teacher should be able to;

1. Explain the first aspect of NOS; Empirical basis; scientific knowledge is based on evidence and observations of nature (specific learning outcomes)

2. Use appropriate basic and integrated science process skills (specific learning outcomes)

3. Design an experiment about testing a plant for starch (specific learning outcomes)

4. Summarize nature and steps testing a plant for starch (specific learning outcomes)

5. Explain variables; affect the photosynthesis (specific learning outcomes)

Which variables affect the photosynthesis?

Introduction

This laboratory experiment will provide you opportunity to understand the first NOS aspect (The Empirical Nature of Scientific Knowledge) and to use necessary basic and integrated SPS.

Preliminary Information

Photosynthesis is a fundamental biological process in which green plants utilize the energy of sunlight to convert carbon dioxide and water into carbohydrates, with the green pigment chlorophyll acting as the energy converter. This process releases oxygen and is the chief source of atmospheric oxygen. Photosynthesis is often described as the most important chemical reaction on earth; it provides green plants with their complete energy requirement, and most other living organisms obtain their own nutrients from these plants, either directly or indirectly. In addition, the process of photosynthesis is the source of oxygen required for the respiration of both plants and animals.

Members of the Kingdom Plantae, together with some members of the Kingdom Protista and all of the cyanobacteria (Kingdom Eubacteria), are photosynthetic organisms; as such, they are autotrophs: they synthesize their own food by using simple raw materials plus the energy of sunlight. Members of the Kingdom Animalia, heterotrophic organisms including human beings, obtain energy from the food they eat.

The process of photosynthesis converts the kinetic energy of sunlight into the potential energy of chemical bonds. The energy is initially trapped in ATP molecules, later incorporated into the bonds of glucose, and eventually stored as carbohydrates—sugar or starch.

Chlorophyll, the photosynthetic pigment in chloroplasts, absorbs light energy. Plants appear green because chlorophyll does not absorb light in the yellow-green region of the visible spectrum. Yellow and green wavelengths of the spectrum are reflected or transmitted by the plant. Chlorophyll absorbs light in the blue and red regions of the spectrum.

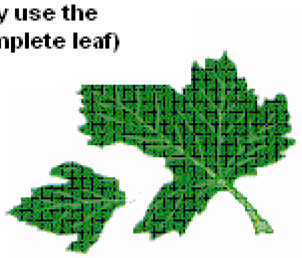
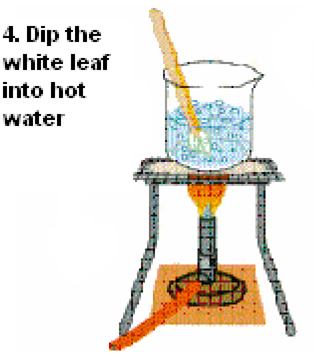
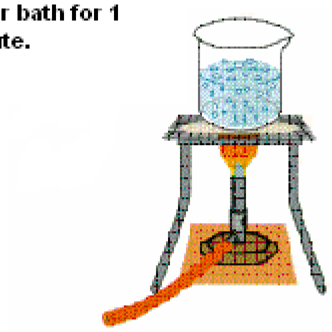
The overall reaction of photosynthesis is:

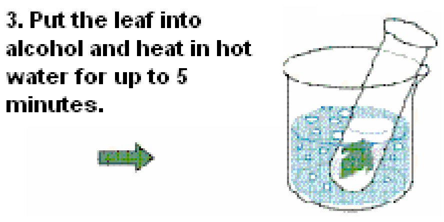
$$\mathbf{6H_2O + 6CO_2 \text{ ----------> } C_6H_{12}O_6 + 6O_2}$$

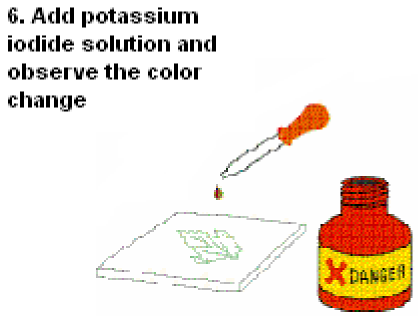
Materials

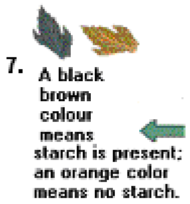
Leaf, Iodine reagent, Alcohol, Water, Bunsen burner, Eye dropper, Test tubes, Beaker, Petri dish, Tripot.

Procedure

1. Remove a small piece of leaf (you may use the complete leaf) 	4. Dip the white leaf into hot water 
2. Place into a boiling water bath for 1 minute. 	5. Spread the leaf on to a white tile or dish 


3. Put the leaf into alcohol and heat in hot water for up to 5 minutes.


6. Add potassium iodide solution and observe the color change
DANGER


7.
A black brown colour means starch is present; an orange color means no starch.

PART A: TESTING A PLANT FOR STARCH

Draw your observations to the given places. Use colored pencils for accurate drawings.

NORMAL LEAF NORMAL LEAF TESTED

WITH IODINE SOLUTION

What is the reason of placing the leaf into a boiling water bath in second step?

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What is the reason of putting the leaf into alcohol and heating it in third second step?

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What is the reason of dipping the white leaf into hot water in fourth step?

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Based on your observations, what is your conclusion about the presence of starch? Did the plant do photosynthesis? Explain.

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PART B: IS LIGHT NEEDED FOR PHOTOSYNTHESIS?

Materials

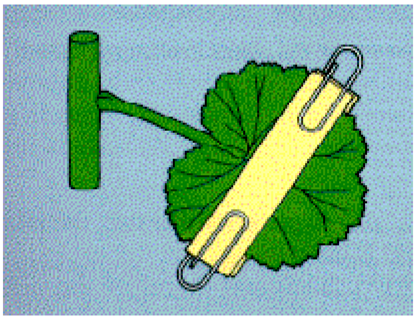
Small shrub, tree or house plant leaf

Aluminium foil, Scissors, Paper clips

Materials required to test starch formation in the leaf

Procedure

1. Pick a shrub. Tree or houseplant leaf that you can use for an experiment.
2. Using the aluminium foil cut out some geometrical shapes like a circle, square or triangle. Make sure your shapes are big enough to make a patch that will cover nearly half of the plant leaf. Cover also an entire leaf with aluminium foil.
3. Paperclip a shape on the leaf so as to block the light.



4. Leave the leaf in a well lit place for four days.
5. After four days, remove the shape from the leaf.
6. Test the leaf for starch.
7. Draw your observations to space provided below. Use colored pencils for accuracy.

What is the reason of covering the leaves with aluminium foil?

What has happened to the leaves? Describe how the lack of sunshine affects the leaves. What has or has not happened in the different parts of the leaf during test for starch?

What can be concluded about the relationship between light and photosynthesis? Describe the relationship. Tell what data supports your conclusion.

PART C: IS CARBON DIOXIDE NEEDED FOR PHOTOSYNTHESIS?

Potted house plants
Soda lime, Sodıum hydrogen carbonate, Polytene bags, Elastic bands

Materials required to test the leaf for starch

Procedure

1. Obtain a potted house plants.
2. Put soda lime to one of the pots. You may put soda lime in a polytene bag and tie up the bag to one of the branches of the plant.
3. Cover the plant with polytene bag and tie up with elastic band. Be sure that the plant is not in contact with air.
4. Wait for two days.
5. Test the plant for starch.
6. Draw your observations to the space provided below. Use colored pencils for accuracy.

What is the function of the soda lime?

Do the leaves stain positively for starch? If not, what may be the reason of this?

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Write a conclusion about the relationship between carbon dioxide and photosynthesis. Tell what data supports your conclusion.

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Examine the new science curriculum. To what extent does the new curriculum cover the photosynthesis unit? According to the new curriculum evaluate the appropriateness of this experiment and write some suggestions about the experiment. Are all parts of the experiment appropriate to elementary students? Are there any parts that need modification? Why? Write your suggestions and modifications about the experiment by considering the new science curriculum.

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Laboratory 2

Name	**:**	
Surname	**:**	
ID Number	**:**	
Section	**:**	

Overview

Rationale

Although science associations and science educators aim to develop conceptions of nature of science (NOS), there is no agreement upon a single definition of nature of science. One of the most famous definitions of NOS related to epistemology of science, science a way of knowing, and related to the values and beliefs inherent to the development of scientific knowledge (Abd-el-Khalick, Bell and Lederman 1998). There are some main aspects of NOS. Some of them are scientific knowledge is empirical based, tentative, and scientific knowledge includes observations and inferences (Schwartz, Lederman & Crawford, 2004).

Science process skills (SPS) are thinking skills that scientists use to construct knowledge, think on problems, and formulate the results (Carin, Bass, & Contant, 2005). Scientists make their discoveries by using their science process skills (Abruscato, 1995). SPS are classified in two different forms; Basic and Integrated SPS. Basic SPS consist of observing, inferring, measuring, communicating, classifying, and predicting. Integrated SPS consist of controlling variables, defining operationally, formulating hypotheses, interpreting data, experimenting, formulating models, and presenting information (Brotherton & Preece, 1995).

In this week we will focus second aspect of NOS; Scientific knowledge includes observations and inferences. Observations and inferences are different.

Objectives

At the end of the laboratory pre service teacher should be able to;

1. Explain the second aspect of NOS; scientific knowledge includes observations and inferences. Observations and inferences are different (specific learning outcomes)

2. Use appropriate basic and integrated science process skills (specific learning outcomes)

3. Design an experiment about the black box (specific learning outcomes)

Black Box. !

Introduction

This laboratory experiment will provide you opportunity to understand the second NOS aspect (Scientific knowledge includes observations and inferences. Observations and inferences are different) and to use necessary basic and integrated SPS.

Preliminary Information

The instructor will demonstrate the Black Box.

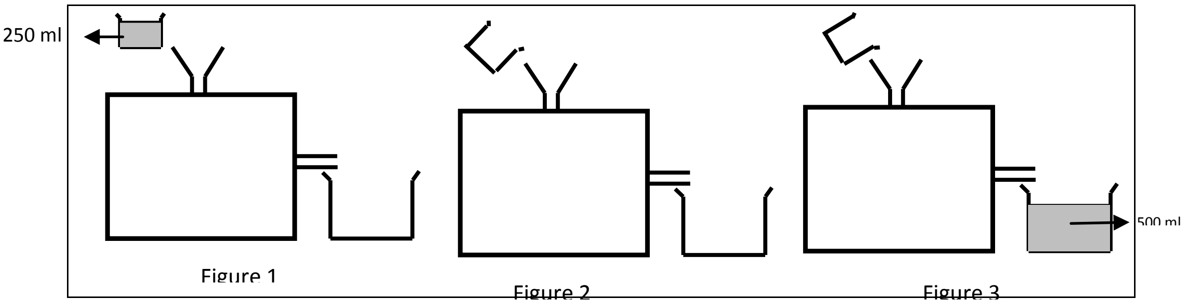

Figure 1 Figure 2 Figure 3

Your research study should include;

10. What is your observation?

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11. State your group purpose

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12. State your group inference about structure in the Black Box?

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13. Determine materials you will use

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14. Write the procedure you will follow

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15. Set up your experimental design

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16. Write your conclusion (your experimental design support your inference or not)

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- Do not forget to write your references if you have.

Laboratory 3

Name	**:**
Surname	**:**
ID Number	**:**
Section	**:**

Overview

Rationale

Although science associations and science educators aim to develop conceptions of nature of science (NOS), there is no agreement upon a single definition of nature of science. One of the most famous definitions of NOS related to epistemology of science, science a way of knowing, and related to the values and beliefs inherent to the development of scientific knowledge. There are some main aspects of NOS. Some of them are scientific knowledge is empirical based, tentative, subjective etc.

Science process skills (SPS) are thinking skills that scientists use to construct knowledge, think on problems, and formulate the results. Scientists make their discoveries by using their science process skills. SPS are classified in two different forms; Basic and Integrated SPS. Basic SPS consist of observing, inferring, measuring, communicating, classifying, and predicting. Integrated SPS consist of controlling variables, defining operationally, formulating hypotheses, interpreting data, experimenting, formulating models, and presenting information.

Third aspect of NOS; theories and laws are different kinds of knowledge and one does not become the other. Laws describe relationships, observed or perceived, of phenomena in nature. Theories are inferred explanations for natural phenomena and mechanisms for relationships among natural phenomena.

Objectives

At the end of the laboratory pre service science teacher should be able to;

1. Understand the third aspect of NOS (instructional objective)

1. Explain the third aspect of NOS; Theories and laws are different kinds of knowledge and one does not become the other (specific learning outcomes)

2. Demonstrate correct usage of a procedure (instructional objective)

2. Use appropriate basic and integrated science process skills (specific learning outcomes)

3. Propose a plan for an experiment (instructional objective)

3. Design an experiment about the law (specific learning outcomes)

4. Understand the theory (instructional objective)

4. Summarize the theory (specific learning outcomes)

The Law of Boyle-Mariotte and The Law of Gravity

Introduction

This laboratory experiment will provide you opportunity to understand the third NOS aspect (Scientific knowledge includes observations and inferences. Observations and inferences are different) and to use necessary basic and integrated SPS.

Preliminary Information

Please choose a law (Boyle-Mariotte or Gravity) and investigate which theory explains your law.

Your research study should include;

17. What is your law and theory?

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18. State your group purpose

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19. State your group hypothesis

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20. Define your variables and write in the below table

	Variables	**Operational Definitions**
Manipulated		
Responding		
Controlled		

21. Determine materials you will use

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22. Write the procedure you will follow

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23. Set up your experimental design

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24. Collect data (observation, measurement), and draw a data table

25. If it is possible according to your experimental design draw a graph based on your data and find the rate.

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26. Write your conclusion (your experimental design support your inference or not)

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- Do not forget to write your references if you have.

Laboratory 4

Name	**:**	
Surname	**:**	
ID Number	**:**	
Section	**:**	

Overview

Rationale

Although science associations and science educators aim to develop conceptions of nature of science (NOS), there is no agreement upon a single definition of nature of science. One of the most famous definitions of NOS related to epistemology of science, science a way of knowing, and related to the values and beliefs inherent to the development of scientific knowledge. There are some main aspects of NOS. Some of them are scientific knowledge is empirical based, tentative, subjective etc.

Science process skills (SPS) are thinking skills that scientists use to construct knowledge, think on problems, and formulate the results. Scientists make their discoveries by using their science process skills. SPS are classified in two different forms; Basic and Integrated SPS. Basic SPS consist of observing, inferring, measuring, communicating, classifying, and predicting. Integrated SPS consist of controlling variables, defining operationally, formulating hypotheses, interpreting data, experimenting, formulating models, and presenting information.

Forth aspect of NOS; the theory-laden nature of scientific knowledge. Scientific knowledge is theory-laden. Scientists' theoretical and disciplinary commitments influence their work.

Objectives

At the end of the laboratory pre service science teacher should be able to;

1. Explain the forth aspect of NOS; the theory-laden nature of scientific knowledge. Scientific knowledge is theory-laden. Scientists' theoretical and disciplinary commitments influence their work (specific learning outcomes)

2. Use appropriate basic and integrated science process skills (specific learning outcomes)

3. Design hypothesis about the theories (specific learning outcomes)

4. Summarize nature the evolution theory (specific learning outcomes)

Evolution theories*

Introduction

This laboratory experiment will provide you opportunity to understand the forth NOS aspect (the theory-laden nature of scientific knowledge. Scientific knowledge is theory-laden. Scientists' theoretical and disciplinary commitments influence their work) and to use necessary basic and integrated SPS.

Preliminary Information

Evolution is seen in the statement that "humans came from apes". This statement assumes that organism evolve through a step-by-step progression from "lower" forms to "higher" forms of life and the direct transformation of one living species into another.

Evolution is not a progressive ladder. Furthermore, modern species are derived from, but are not the same as, organism that lived in the past.

Did human evolve from modern apes, or do modern apes and humans have a common ancestor? Do you understand the differences between these two questions?

This activity will give you the opportunity to observe differences and similarities in the characteristics of humans and apes. The apes discussed in this activity are the chimpanzee and the gorilla.

Please find the morphological relationships between gorillas, chimpanzees, and humans.

Modern research techniques allow biologists to compare the DNA that codes for certain proteins and to make predictions about the relatedness of the organisms from which they took the DNA. Students will use models of these techniques to test their hypotheses and determine which one is best supported by the data they develop.

Working in groups of four, “synthesize” strands of DNA according to the following specifications. Each different each different color of paper clip represents one of the four bases of DNA.

Materials

Four sets of black, white, green, and red paper clips, each set with 35 paper clips.

Black: adenine (A) Green: guanine (G)

White: thymine (T) Red: cytosine (C)

Procedure

Each student will synthesize one strand of DNA. Thirty-five paper clips of each color should provide an ample assortment.

Group member 1: Synthesize a strand of DNA that has the following sequence:

A-G-G-C-A-T-A-A-A-C-C-A-A-C-C-G-A-T-T-A

Label this strand “human DNA”, this strand represents a small section of the gene that codes for human hemoglobin protein.

Group member 2: Synthesize a strand of DNA that has the following sequence:

A-G-G-C-C-C-C-T-T-C-C-A-A-C-C-G-A-T-T-A

Label this strand “chimpanzee DNA”, this strand represents a small section of the gene that codes for human hemoglobin protein.

Group member 3: Synthesize a strand of DNA that has the following sequence:

A-G-G-C-C-C-C-T-T-C-C-A-A-C-C-A-G-G-C-C

Label this strand “gorilla DNA”, this strand represents a small section of the gene that codes for human hemoglobin protein.

Group member 4: Synthesize a strand of DNA that has the following sequence:

A-G-G-C-C-G-G-C-T-C-C-A-A-C-C-A-G-G-C-C

Label this strand "common ancestor DNA", this strand represents a small section of the gene that codes for human hemoglobin protein of a common ancestor of the gorilla, chimpanzee, and human.

Your research study should include;

1. State your group purpose

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2. State your group hypothesis to explain how these organisms are related? (Three hypothesis or two hypothesis according to your theory)

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3. Compare the human DNA to the chimpanzee DNA by matching the strands base by base (paper clip by paper clip). Count the number of bases that are not the same. Record the data in a table. Repeat the steps with the human DNA and the gorilla DNA.

Hybridization data for human DNA

Human DNA compared to:	**Number of matches**	**Unmatched bases**
Chimpanzee DNA		
Gorilla DNA		

How do the gorilla DNA and the chimpanzee DNA compare with the human DNA?

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....

....

....

....

Data for common ancestor DNA

Common ancestor DNA compared to:	**Number of matches**	**Unmatched bases**
Human DNA		
Chimpanzee DNA		
Gorilla DNA		

What do these data suggest about the relationship between humans, gorillas, and chimpanzees?

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4. Write your conclusion. Do the data support any of your hypotheses? Why or why not?

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* National Academy of Sciences (1998). Teaching about Evolution and the Nature of Science. Washington, D.C: National Academy Press.

- Do not forget to write your references if you have.

Laboratory 5

Name	:
Surname	:
ID Number	:
Section	:

Overview

Rationale

Although science associations and science educators aim to develop conceptions of nature of science (NOS), there is no agreement upon a single definition of nature of science. One of the most famous definitions of NOS related to epistemology of science, science a way of knowing, and related to the values and beliefs inherent to the development of scientific knowledge. There are some main aspects of NOS. Some of them are scientific knowledge is empirical based, tentative, subjective etc.

Science process skills (SPS) are thinking skills that scientists use to construct knowledge, think on problems, and formulate the results. Scientists make their discoveries by using their science process skills. SPS are classified in two different forms; Basic and Integrated SPS. Basic SPS consist of observing, inferring, measuring, communicating, classifying, and predicting. Integrated SPS consist of controlling variables, defining operationally, formulating hypotheses, interpreting data, experimenting, formulating models, and presenting information.

The fifth aspect of NOS; the tentative nature of scientific knowledge. Scientific knowledge, although reliable and durable, is never absolute or certain. Scientific knowledge is subject to change with new observations and with the reinterpretations of existing new knowledge.

Objectives

At the end of the laboratory pre service science teacher should be able to;

1. Explain the fifth aspect of NOS; the tentative nature of scientific knowledge. Scientific knowledge, although reliable and durable, is never absolute or certain. Scientific knowledge is subject to change with new observations and with the reinterpretations of existing new knowledge (specific learning outcomes).

2. Use appropriate basic and integrated science process skills (specific learning outcomes)

3. Determine the age of fossils (specific learning outcomes)

Age of Fossils

Introduction

This laboratory experiment will provide you opportunity to understand the fifth aspect of NOS (The tentative nature of scientific knowledge. Scientific knowledge, although reliable and durable, is never absolute or certain. Scientific knowledge is subject to change with new observations and with the reinterpretations of existing new knowledge) and to use necessary basic and integrated SPS.

Preliminary Information

Instructor gives each group fossil fragments. These fossils lived diffrent times before Christ.

Materials

Fossils fragments, hand magnifying glass

Your research study should include;

1. Please classify these fossils for six classes, and draw a sample for each class in the below cells.

1.	2.	3.
4.	5.	6.

2. Please set the classes in the below timeline

BC 10000	BC 8000	BC 6000	BC 4000	BC 2000	BC 1000
……….	………..	………..	………….	………	……….

Please be sure complete the timeline and follow the instructor suggestions.

3. New information
   1;...

What is your hypothesis about new ordering based on new information?

....
....
....
....
....
....
....

Please replace the classes in the below timeline according to your hypothesis.

BC 10000	BC 8000	BC 6000	BC 4000	BC 2000	BC 1000
……….	………..	………..	………….	………	……….

Please be sure complete the timeline and follow the instructor suggestions.

4. New information 2;...

What is your hypothesis about new ordering based on new information?

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....
....

Please replace the classes in the below timeline according to your hypothesis.

BC 10000	BC 8000	BC 6000	BC 4000	BC 2000	BC 1000
……….	………..	………..	………….	………	……….

Please be sure complete the timeline and follow the instructor suggestions.

5. New information 3; …………………………………………………………………...

What is your hypothesis about new ordering based on new information?

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Please replace the classes in the below timeline according to your hypothesis.

BC 10000	BC 8000	BC 6000	BC 4000	BC 2000	BC 1000
……….	………..	………..	………….	………	……….

Please be sure complete the timeline and follow the instructor suggestions.

6. New information 4;

   ……………………………………………………………………...

What is your hypothesis based on new information?

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Please replace if it is necessary the classes in the below timeline according to your hypothesis.

BC 10000	BC 8000	BC 6000	BC 4000	BC 2000	BC 1000
……….	………..	………..	………….	………	……….

Please be sure complete the timeline.

7. Please explain did you change ordering timeline according to given new information? Which information caused great changing? Which information caused little changing?

   ....

   ....

   ....

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   ....

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   *Do not forget to write your references if you have.

INFORMATIONS

New information 1: According to geologists; between 1st and 2nd timeline, it was seen that expansion has occurred among strong layers because of volcanic eruption. This expansion caused to change sizes of unicellular livings.

New information 2: According to geologists; between 2nd and 3rd timeline, the expansion which was seen before, has continued vertically.

New information 3: According to geologists; between 3rd and 4th timeline, it was seen that sizes of unicellular livings shrinked because of ocean movement.

New information 4: According to geologists; between 4th and 5th timeline, unicellular livings changed their structure of skin to accommodate their environments.

New information 5: According to geologists; between 5th and 6th timeline, unicellular livings which had changed their structure of skin before, had a more extended habitat.

Laboratory 6

Name	:
Surname	:
ID Number	:
Section	:

Overview

Rationale

Although science associations and science educators aim to develop conceptions of nature of science (NOS), there is no agreement upon a single definition of nature of science. One of the most famous definitions of NOS related to epistemology of science, science a way of knowing, and related to the values and beliefs inherent to the development of scientific knowledge. Science process skills (SPS) are thinking skills that scientists use to construct knowledge, think on problems, and formulate the results. Scientists make their discoveries by using their science process skills. SPS are classified in two different forms; Basic and Integrated SPS. Basic SPS consist of observing, inferring, measuring, communicating, classifying, and predicting. Integrated SPS consist of controlling variables, defining operationally, formulating hypotheses, interpreting data, experimenting, formulating models, and presenting information.

The sixth aspect of NOS; the creative and imaginative nature of scientific knowledge. Scientific knowledge is created from human imaginations and logical reasoning. This creation is based on observations and inferences of the natural world.

Objectives

At the end of the laboratory pre service teacher should be able to;

1. Explain the sixth aspect of NOS; the creative and imaginative nature of scientific knowledge. Scientific knowledge is created from human imaginations and logical reasoning. This creation is based on observations and inferences of the natural world (specific learning outcomes)

2. Use appropriate basic and integrated science process skills (specific learning outcomes)

3. Design a study about the fossil fragments (specific learning outcomes)

4. Draw the fossil fragments (specific learning outcomes)

Real Fossils*

Introduction

This laboratory experiment will provide you opportunity to understand the sixth NOS aspect (Scientific knowledge is created from human imaginations and logical reasoning. This creation is based on observations and inferences of the natural world) and to use necessary basic and integrated SPS.

Preliminary Information

Instructors give each group six fossil fragments and ask them to make a detailed diagram of it (each student will choose a fragment).

Please attention; each student should bring own overhead transparency and two different colored overhead transparency pens.

Materials

Fossils fragments (not complete fossils), a ruler, a magnifying glass.

Please attention; each student should bring own overhead transparency and two different colored overhead transparency pens.

Your research includes;

27. Please make a detailed diagram of it; the diagrams may be larger than the actual fragments. (Use only one color when drawing your fossil fragment. Place the drawing near the middle of the sheet. You may enlarge your drawing of the fossils to show more detail).

* Draw your fossil fragment on the overhead transparency using one of their two pens.

2. Draw the rest of the organism represented by your fossil fragment using a pen of another color on above sheet and your overhead transparency. Your drawing may include other features of the organism's habitat that are indicative of the way the organism fits into its environment (what it eats and other factors related to its survival). End up with a drawing of an organism from which, you believe, the fossil fragment has come.

3. Please identify the observation part of the drawing (drawing of the original fossil fragment in one color) and the inference part of the drawing (drawing of the rest of the organism and its habitat in the alternative color).

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4. Which characteristics of the fossil led you to infer this particular organism and environment?

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5. How were you able to infer a complete organism and environment from a tiny piece of fossil?

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……………………………………………………………….

6. Why did some of you, who received same fossil fragments, draw very different creatures?

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7. Would paleontologists reach the same conclusion about the identity of the organism and its environment as you did? If "No" Why?

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- Do not forget to write your references if you have.

Laboratory 7

Name	**:**	
Surname	**:**	
ID Number	**:**	
Section	**:**	

Overview

Rationale

Although science associations and science educators aim to develop conceptions of nature of science (NOS), there is no agreement upon a single definition of nature of science. One of the most famous definitions of NOS related to epistemology of science, science a way of knowing, and related to the values and beliefs inherent to the development of scientific knowledge. There are some main aspects of NOS. Some of them are scientific knowledge is empirical based, tentative, subjective etc.

Science process skills (SPS) are thinking skills that scientists use to construct knowledge, think on problems, and formulate the results. Scientists make their discoveries by using their science process skills. SPS are classified in two different forms; Basic and Integrated SPS. Basic SPS consist of observing, inferring, measuring, communicating, classifying, and predicting. Integrated SPS consist of controlling variables, defining operationally, formulating hypotheses, interpreting data, experimenting, formulating models, and presenting information.

In this week we will focus seventh aspect of NOS; The social and cultural embeddedness of scientific knowledge. Science as a human enterprise is practiced in the context of a larger culture and its practitioners are the product of that culture.

Science, it follows, affects and is affected by the various elements and intellectual spheres of the culture in which it is embedded. These elements include, but are not limited to, social fabric, power structures, politics, socioeconomic factors, philosophy, and religion.

Objectives

At the end of the laboratory pre service teacher should be able to;

1. Explain the seventh aspect of NOS; The social and cultural embeddedness of scientific knowledge. (specific learning outcomes)

2. Use appropriate basic and integrated science process skills (specific learning outcomes)

3. Design an experiment about mixture of water (specific learning outcomes)

Which water!!!

Introduction

This laboratory experiment will provide you opportunity to understand the seventh NOS aspect (The social and cultural embeddedness of scientific knowledge) and to use necessary basic and integrated SPS.

Materials

Soil, plastic container, water, thermometer, …… (lab materials)

Your research study should include;

1. State your group purpose

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....
....

2. State your group hypothesis

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3. Define your variables and write in the below table

	Variables	Operational Definitions
Manipulated		
Responding		
Controlled		

4. Determine materials you will use

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5. Write the procedure you will fallow

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6. Draw your experimental design

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7. Collect data (observation, measurement), and draw a data table (if necessary)

8. Draw a graph based on your data and find the rate (if necessary)

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9. Write your conclusion

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- Do not forget to write your references if you have.

APPENDIX C

Semi-structured interview questions

1- Is there any relationship between scientific knowledge and experimentation-observation?
   - Can you explain your answer with an example from the first laboratory class?
   - Is there any relationship among nature of science, science process skills, and scientific knowledge?
   - Can you give any example related to science process skills which used in the first laboratory class?

2- Is there any relationship between scientific knowledge and observation-inference?
   - Can you explain your answer with an example from the second laboratory class?
   - Is there any relationship among nature of science, science process skills, and scientific knowledge?
   - Can you give any example related to science process skills used in the second laboratory class?

3- Is there any difference between theory and law? Can you compare these in terms of scientific knowledge?
   - Can you explain your answer with an example from the third laboratory class?
   - Is there any relationship among nature of science, science process skills, and scientific knowledge?
   - Can you give any example related to science process skills used in the third laboratory class?

4- Is there any relationship between scientific knowledge and theory?
   - Can you explain your answer with an example from the fourth laboratory class?
   - Is there any relationship among nature of science, science process skills, and scientific knowledge?
   - Can you give any example related to science process skills used in the fourth laboratory class?

5- Is scientific knowledge tentative?
  - Can you explain your answer with an example from the fifth laboratory class?
  - Is there any relationship among nature of science, science process skills, and scientific knowledge?
  - Can you give any example related to science process skills used in the fifth laboratory class?

6- Is there any relationship between scientific knowledge and creativity and imagination?
  - Can you explain your answer with an example from the sixth laboratory class?
  - Is there any relationship among nature of science, science process skills, and scientific knowledge?
  - Can you give any example related to science process skills used in the sixth laboratory class?

7- Is there any relationship between scientific knowledge and social-cultural environment?
  - Can you explain your answer with an example from the seventh laboratory class?
  - Is there any relationship among nature of science, science process skills, and scientific knowledge?
  - Can you give any example related to science process skills used in the seventh laboratory class?

8- What do you think about satisfactoriness all of the laboratory activities according to their aims of nature of science aspects from first week to seventh week?
  - Were these activities adequate, or inadequate?
  - Can you explain your answer with an example from the laboratory classes? (For each week)

9- What do you think about learning nature of science in laboratory environment?
  - Is there any advantages or disadvantages?
  - Can you explain your answer with an example from the laboratory classes?

10- In the future, you will be a teacher, will you use these or similar activities in science laboratory to teach nature of science?
  - Yes or no, can you explain your answer?

APPENDIX D

Quizzes

Quiz 1

Name:

Photosynthesis

1- Generally, what do plants require to meet the demands of their metabolic activities?

a. Carbohydrates, light, water and nitrogen

b. Light, oxygen, carbon dioxide, water, and minerals

c. Carbon dioxide, oxygen, proteins and minerals

d. Water, carbohydrates, proteins, and minerals

2- Write the reaction of photosynthesis.

___________ + _____________ ⟶ ___________________ + _________

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Quiz 2

Name:

1-Define observation and inference.

2-What is the differences between observation and inference?

Quiz 3

Name:

1-Define theory and law.

2- Which of the laws did you choose for this week, and which of the theory explain your law?

Quiz 4

Name:

1- Explain the aspect of NOS (the theory-laden nature of scientific knowledge).

2- “Did human evolve from modern apes, or do modern apes and humans have a common ancestor?” What is the difference between these two questions?

Quiz 5

Name:

1- What do you understand from “the tentative nature of scientific knowledge”? Please explain briefly in <u>your own words</u>. (4 pts)

2- Please write two objectives in cognitive domain related to this week’s laboratory activity and be careful about the objective writing rules. (4 pts)

At the end of the laboratory pre service teacher shoul be able to;

a)...
....

b)...
....

3- What are the materials that are going to be used in this laboratory activity? (2 pts)

a)...........................

b)...........................

Quiz 6

Name:

1- What is the difference between science and art? (7 pts)

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…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………

2- What are the materials that are going to be used in this laboratory activity? (3 pts)

a)...........................

b)...........................

Quiz 7

Name:

1- What is the aspect of NOS that is going to be dealt with this week? Please explain briefly in <u>your own words</u>. (4 pts)

……………………………………………………………………
……………………………………………………………………
……………………………………………………………………
………………………………………

2- What is the other objective of this laboratory session except the two followings? (4 pts)

a. Explain the seventh aspect of NOS.

b. Use appropriate basic and integrated science process skills.

c. ……………………………………………………………………………

3- What are the materials that are going to be used in this laboratory activity? (2 pts)

a. ....

APPENDIX E

Reflection papers

Reflection Paper 1

Name:

By considering the processes that you followed to conduct germination of a bean experiment and photosynthesis, please answer the following questions.

1- Explain the aspect of NOS (Empirical basis; scientific knowledge is based on evidence and observations of nature) in your own words. Please relate the aspect of NOS to the experiment that you designed (conducted) in this week.

2- Write the basic and integrated science process skills that you used to conduct the photosynthesis and Germination Experiment.

3- What do you think about the role(s) of SPS to understand the aspect of NOS?

Reflection Paper 2

Name:

By considering the processes that you followed to conduct Black Box experiment please answer the following questions.

1- Explain the aspect of NOS (Scientific knowledge includes observations and inferences. Observations and inferences are different) in your own words. Please relate the aspect of NOS to the experiment that you designed (conducted) in this week.

2- Write the basic and integrated science process skills that you used to conduct the Black Box Experiment.

3- What do you think about the role(s) of SPS to understand the aspect of NOS?

Reflection Paper 3

Name:

By considering the process that you followed to conduct your experiment, please answer the following questions;

1- Explain the aspect of NOS (Theories and laws are different kinds of scientific knowledge. Laws describe relationships, observed or perceived, of phenomena in nature. Theories are inferred explanations for natural phenomena and mechanisms for relationships among natural phenomena) in your own words. Please relate the aspect of NOS to the experiment that you designed (conducted) in this week.

2- Write the basic and integrated science process skills that you used to conduct the law and theory experiment.

3- What do you think about the role(s) of SPS to understand the aspect of NOS?

Reflection Paper 4

Name:

By considering the process that you followed to conduct the Fossils experiment, please answer the following questions;

1- Explain the aspect of NOS (The tentative nature of scientific knowledge. Scientific knowledge, although reliable and durable, is never absolute or certain.) in your own words. Please relate the aspect of NOS to the experiment that you designed (conducted) in this week.

2- Write the basic and integrated science process skills that you used to conduct the Fossils activity.

3- What do you think about the role(s) of SPS to understand the aspect of NOS?

Reflection Paper 5

Name:

By considering the process that you followed to conduct the Fossils theories experiment, please answer the following questions;

1- Explain the aspect of NOS (The tentative nature of scientific knowledge. Scientific knowledge, although reliable and durable, is never absolute or certain.) in your own words. Please relate the aspect of NOS to the experiment that you designed (conducted) in this week.

2- Write the basic and integrated science process skills that you used to conduct the Fossils activity.

3- What do you think about the role(s) of SPS to understand the aspect of NOS?

Reflection Paper 6

Name:

By considering the process that you followed to conduct the fossils experiment, please answer the following questions;

1- Explain the aspect of NOS (The creative and imaginative nature of scientific knowledge. Scientific knowledge is created from human imaginations and logical reasoning. This creation is based on observations and inferences of the natural world) in your own words. Please relate the aspect of NOS to the experiment that you designed (conducted) in this week.

2- Write the basic and integrated science process skills that you used to conduct the fossils experiment.

3- What do you think about the role(s) of SPS to understand the aspect of NOS?

Reflection Paper 7

Name:

By considering the process that you followed to conduct the experiment about water, please answer the following questions;

1- Explain the aspect of NOS (The social and cultural embeddedness of scientific knowledge. Science as a human enterprise is practiced in the context of a larger culture and its practitioners are the product of that culture.) in your own words. Please relate the aspect of NOS to the experiment that you designed (conducted) in this week.

2- Write the basic and integrated science process skills that you used to conduct the experiment.

3- What do you think about the role(s) of SPS to understand the aspect of NOS?

Appendix F:

Coding Schema for Comparing NOS Views with Reforms

NOS Aspect	Consistent with Reforms	Partially Consistent with Reforms	Inconsistent with Reforms
Durability and tentativeness	Recognizes that while it is durable, *all* scientific knowledge is subject to change with new evidence (adding to) or the reinterpretation of existing evidence (reconceptualization).	Recognizes that scientific knowledge can change; however may emphasize durability over tentativeness. For example, states that scientific laws are "set in stone" and are unlikely to change.	Views scientific knowledge as an accumulation of facts that are absolute, proven, and unchanging.
Subjective/ theory-laden	Recognizes that human subjectivity is inherent in all scientific work. Recognizes that current theories serve as a lens through which we view data, and guides future work.	Understands that subjectivity can play a role in the development of scientific knowledge; however this viewed as bias/ unethical conduct by scientists.	Views science/scientists as objective and value-free. Differing interpretations occur because it can't be determined which explanation is "right."
Inferential	Recognizes that it is not possible to directly observe all phenomena; however, through indirect evidence it is possible to make logical inferences about these phenomena.	Recognizes use of both observation and inference in science; however, may still focus on an ultimate need for direct observation as evidence.	Ascribes to the notion that "seeing is believing" and fails to recognize the role of indirect evidence in science.
Empirical	Recognizes scientific claims must be based on empirical evidence (whether direct or indirect) and that they are limited to natural phenomena.	Refers to "data" and "testing," however, may not recognize this as distinguishing science from other disciplines of inquiry (e.g., religion). May focus on science as a democracy/ role of consensus.	Fails to recognize reliance on evidence to support scientific claims. May emphasize individual beliefs and opinions over evidence.
Creativity & imagination	Considers creativity/imagination a vital part of all stages of scientific investigations (not only planning/interpretation). Recognize that ideas (theories, hypotheses) are created.	Recognizes role of creativity and imagination in scientific investigation; however, may indicate that some aspects do not/ should not involve creativity (ex: data collection)	Views science as procedural, rather than creative.
Socio-cultural context	Recognizes that science, as a human endeavor, both influences and is influenced by society and culture. May view science as a culture unto itself.	Recognizes either the influence of society/ culture on science or vice versa (but not both). May emphasize science as "universal" in ontological terms, as in describing a single reality.	Views science as universal and/or separate from the society/culture in which it is practiced.
Theories and laws	Recognizes theories and laws as end product of science, and distinct from one another. Understands that laws are primarily descriptive of relationships between variables and that theories may explain or encompass laws.	Recognizes that theories and laws are fundamentally different (theories do not become laws) however, unable to articulate clear definitions, provide examples, etc.	Holds a hierarchal view of the function and relation of theory and law, in which theories (untested speculations) become laws (proven facts).

Appendix G

Turkish versions of the quotations from interviews

PST #16 (Preservice science teacher number 16 from interview): Certainly, experiments are important in science, because reaching scientific knowledge is difficult without experimentation. In order to show the reality of something we need to show cause effect relationships, thus, we need experiments. Experiments are the first step for scientific knowledge. Results of experiments are not different according to people, thus this support reliability for knowledge.

PST #16 (Fen Bilgisi öğretmen adayı, numara 16, mülakat): Kesinlikle deneyin önemi var, deneysiz gözlemsiz bilimsel bilgiye ulaşmak zor olur. Bir şeyin gerçekliğini anlatmak için sebep-sonuç ilişkisini dolayısıyla deneylere ihtiyacımız vardır. Deneyler bilimsel bilgiye ulaşmada ilk adımdır. Deneylerin sonuçları insanlara göre değişmez, buda bilginin güvenilir olmasını sağlar.

PST #35 from interview: In the laboratory, we observed directly the box; we stated our observation without interpretations. For inference, we tried to discovery a system inside the box. In the laboratory, our observations were same but our inferences were different.

PST #35 Mülakat; Laboratuarda direk olarak kutuyu gözlemledik ve yorumumuzu katmadan gözlemlerimizi kaydettik. Çıkarım için kutunun içindeki sistemi keşfetmeye çalıştık. Laboratuarda gözlemlerimiz aynıydı fakat çıkarımlarımız farklıydı.

PST #32 from interview: Especially, for some science topics we have to infer, for example, about atom, about universe, and evolution we cannot do experiments. By means of inferences, we formed models to explain some topics. In the laboratory we observed the box, we could not see inside, thus we made some inferences about its system, I think this was important.

PST #32 Mülakat; Özellikle bazı konularda çıkarım yapmak zorundayız, mesela atom hakkında, evren hakkında ya da evrim konularında deney yapabilmemiz mümkün değildir. Bu tür konuları açıklamak için çıkarımlar yoluyla modeller oluşturulur. Laboratuarda biz kutuyu gözlemledik, içini görmemiz mümkün değildi, bundan dolayı bazı çıkarımlar yaptık, bence bu önemliydi.

PST #13 from interview: In laboratory, we did not see inside the box, we did inferences. I understand scientists made some inferences about unobservable things and they reach scientific knowledge. We observed same thing but we had different designs.

PST #13 Mülakat; Laboratuarda kutunun içini görmedik sadece çıkarım yaptık. Bilim insanlarının görülemeyen şeyle hakkında çıkarım yapıp bilimsel bilgiye ulaşabildiklerini anladım. Aynı şeyi gözlemledik fakat farklı çıkarımlarımız oldu.

PST #38 from interview; Before this activity I thought that theories become laws and laws cannot change, because this knowledge was taught us, every person in the laboratory had these wrong conceptions. In the science books, there were graphics [show vertical relationships among hypothesis to law], thus we learned wrongly.

PST #38 Mülakat; Bu etkinlikten önce teorilerin yasalara dönüşeceğini ve yasaların değişmeyeceğini düşünüyordum, çünkü bunlar bize böyle öğretildi, laboratuardaki herkes bu tür yanlış kavramlara sahipti. Fen kitaplarında bununla ilgili grafikler vardı [hipotezden yasaya dikey ilişkiyi gösteriyordu], bunsan dolayı bizler yanlış öğrendik.

PST #10 from interview: In this laboratory, we used Boyle-Mariotte law, and we designed an activity, to explain relationship between pressure and volume we used molecular kinetic theory. Theories try to explain laws.

PST #10 Mülakat; Bu laboratuar da biz Boyle-Mariotte yasasını kullandık, ve bir etkinlik dizayn ettik. Basınç ve hacim arasındaki

ilişkiyi göstermek için moleküler kinetik teoriyi kullandık.
Teoriler yasaları açıklamaya çalışır.

PST #1 from interview: I think scientists are affected [by their] existing theories while conducting research. In the laboratory, we formulated some hypotheses according to our theory. Different groups had different hypotheses because of the different theories. At the end, every group reached different results from the same data, but all of the results were acceptable.

PST #1 Mülakat; Bence bilim insanları araştırma yaparken var olan teorilerden etkilenirler. Laboratuar da kendi teorimize göre bazı hipotezler geliştirdik. Farklı gruplar farklı teorilerden dolayı farklı hipotezler kurdular. Sonuçta, her grup aynı veriden farklı sonuçlara ulaştı, fakat bütün bu farklı sonuçlar kabul edilebilirdi.

PST #15 from interview: In laboratory, we were given DNA strands, there were two different theories about evolution. We had same data but at the end, we supported different hypotheses. I understand that scientific knowledge is affected from existed theories. Theories can guide research. In this activity, we formulated our hypothesis according to our theory.

PST #15 Mülakat; Laboratuar da bize DNA molekülleri ve iki farklı evrim teorisi verildi. Bütün gruplar aynı veriye sahipti, fakat sonunda herkes farklı hipotezleri destekledi. Bilimsel bilginin var olan teorilerden etkilendiğini anladım. Teoriler araştırmaları yönlendirebilir. Bu etkinlikte kendi teorimize göre hipotezler kurduk.

PST #21 from interview: I think during scientific investigation scientists are affected existed theories normally. In this activity, we used same data but we had different theories, our conclusions were different. Our expectations were affected from our theories. Scientists can reach different results from same data. I understood science is subjective, not objective. Especially, there are some subjects are very controversial, for example evolution.

PST #21 Mülakat; Bence bilimsel araştırma yapılırken bilim insanlarının var olan teorilerden etkilenmesi normaldir. Bu etkinlikte biz aynı veriyi kullandık ama farklı teorilerimiz vardı, sonuçlarımız farklı oldu. Beklentilerimiz bizim teorilerimizden etkilendi. Bilim insanları aynı veriden farklı sonuçlara ulaşabilirler. Bilimin objektif değil sübjektif olduğunu anladım. Özellikle bazı konular var ki çok tartışmalı mesela evrim.

PST #27 from interview: In the laboratory, we supported different theories using same data. I understand scientists can use scientific data according to their target or something they want to support. I think this related to subjectivity in science. Scientists use previous theories to analyze present data. If there are some different theories about a topic, scientists can select one of them according to their previous knowledge or their beliefs. For example, some scientists support evolution theory for origin of species, some others can support creationism. This is controversial topic, and I think scientists are not objective.

PST #27 Mülakat; Laboratuar da aynı verileri kullanarak farklı teorileri destekledik. Bilim insanlarının kendi amaçlarına göre bilimsel verileri kullanabileceklerini anladım. Bence, bu bilimin sübjektif olmasıyla alakalı. Bilim insanları günümüzdeki verileri analiz etmek için geçmişteki teorileri kullanırlar. Eğer bir konu hakkında farklı teoriler varsa, bilim insani geçmiş bilgilerine ya da inançlarına bağlı olarak içlerinden birini seçebilir. Mesela bazı bilim insanları türlerin kökeni olarak evrim teorisini desteklerken bazıları da yaratıcılığı desteklemektedirler. Bu tartışmalı bir konu, bence bilim insanları objektif değiller.

PST #23 from interview: I understand different scientists can be affected different theories according to their culture and their previous knowledge. For example, there are different theories about extinction of dinosaurs.

PST #23 Mülakat; Bilim insanlarının kendi kültürlerine ve önceki bilgilerine bağlı olarak farklı teorilerden etkilendiklerini anlıyorum. Mesela dinozorların yok oluşuyla ilgili bilim adamlarının destekledikleri farklı teoriler var.

PST #11 from interview: In the past scientific knowledge changed, thus scientific knowledge can change. In laboratory, we ordered fossils we used our knowledge and our creativity, after new knowledge came we changed our sorting. However, this characteristic does not mean science is unimportant, today we use scientific knowledge, which can be changed in future.

PST #11 Mülakat; Bilimsel bilgi değişebilir, geçmişte değişmiştir. Laboratuar da kendi bilgimizi ve yaratıcılığımızı kullanarak fosilleri sıraladık. Yeni bilgiler geldikçe var olan sıralamayı değiştirdik. Fakat bu değişebilir olma bilimsel bilginin önemsiz olduğu anlamına gelmez, günümüzde kullandığımız bilgiler gelecekte değişebilir.

PST #40 from interview: Scientific knowledge can be changed in time. New knowledge can change existing knowledge. I understand that, scientific knowledge is not absolute and not stable it is subject to change. In the laboratory, we observed fossils and ordered, then new knowledge came we changed our order.

PST #40 Mülakat; Bilimsel bilgi zamanla değişebilir. Yeni bilgi var olanı değiştirebilir. Bilimsel bilgi kesin ve sabit değildir, değişime açıktır. Laboratuar da fosilleri gözlemledik ve sıraladık, yeni bilgi geldiğinde sıralamamızı değiştirdi.

PST #7 from interview: Scientific knowledge is changeable, but this is not deficiency for science. Science does not include absolute scientific knowledge, thus new information can change existed knowledge, and this develops science.

PST #7 Mülakat; Bilimsel bilgi değişebilir, fakat bu bilimsel bilgi için bir eksiklik değildir. Bilimde kesin bilgi yoktur, bundan dolayı yeni bilgiler her zaman var olanı değiştirebilir ve buda bilimi geliştirir.

PST #3 from interview: I think science change continuously. It changes slowly but it changes. In the past people made something, they were changed today, tomorrow our scientific knowledge will be changed, and thus science will be developed. Everything is changeable.

PST #3 Mülakat; Bence bilim sürekli olarak değişir. Bilimin değişmesi yavaştır ama değişim devam eder. Geçmişte insanların yaptığı şeyler bugün değişti, yarın da bizim bilgilerimiz değişecek ve böylece bilim gelişecek. Her şey değişebilir.

PST #4 from interview: I believe that scientific knowledge should be change, because its changing causes its development. If we accept that scientific knowledge does not change, anybody try to develop it. However, if we accept it can be changed, people try to find new things and investigate continuously. Moreover, science related to nature and nature changes continuously, thus science should change, this causes development.

PST #4 Mülakat; Bence bilimsel bilgi değişmelidir, çünkü onun değişmesi gelişime neden olur. Eğer biz bilimsel bilginin değişmeyeceğini kabul edersek, hiç kimse onu geliştirmek için caba harcamaz. Fakat biz onun değişebilir olduğunu kabul edersek, insanlar yeni bir şeyler bulmak için sürekli olarak araştırmaya devam ederler. Ayrıca bilim doğayla ilişkilidir ve doğada sürekli olarak değişiyor, bundan dolayı bilimde değişmelidir, değişim gelişimi sağlar.

PST #28 from interview: In laboratory, we draw different creatures from the same fossils' fragments. I understand science is affected from scientists' creativity and imagination. I think some theories are product of creativity; for example, relativistic theory.

PST #28 Mülakat; Laboratuar da aynı fosil parçaları için farklı canlılar çizdik. Bilimin bilim insanlarının hayal gücünden ve yaratıcılığından etkileneceğini anladım. Bence bazı teoriler yaratıcılığın bir ürünüdür; mesela rölativistlik teori.

PST #43 from interview: We draw different creatures from same fossils. Because of our creativities and imaginations were different. I think scientists are affected from their creativities and imagination, because their human beings like us.

PST #43 Mülakat; Aynı fosil parçaları için farklı canlılar çizdik, çünkü bizim hayal gücümüz ve yaratıcılığımız farklı. Bence bilim insanları kendi hayal güçlerinden etkilenirler, çünkü onlar da bizim gibi insanlar.

PST# 13 from interview: I think scientists' creativity and imagination affect scientific knowledge. In the laboratory, some friends and I had same fossil, but we drew differently according to our imagination and creativity. When I saw my friends' different drawings, I was shocked. They were very different.

PST# 13 Mülakat; Bence bilim insanlarının hayal güçleri ve yaratıcılıkları bilimsel bilgiyi etkiler. Laboratuar da bazı arkadaşlar ve bende aynı fosil parçası vardı, fakat bizim çizimlerimiz hayal güçlerimizin farklılığından dolayı farklıydı. Arkadaşlarımın farklı çizimlerini gördüğüm zaman şok oldum, çünkü onlar çok farklıydı.

PST #5 from interview: In laboratory class we had same fossil fragments, but every people drawn differently fossils' remaining parts. Because of, every people had different imagination. Thus, imagination and creativity affected our drawings. We saw that in science scientists' imagination affect their works.

PST #5 Mülakat; Laboratuar da biz aynı fosil parçalarına sahiptik, fakat herkes farklı şeyler çizdi. Çünkü herkes farklı hayal güçlerine sahiptir. Bundan dolayı hayal gücü ve yaratıcılık bizim çizimlerimizi etkiledi. Bilimin bilim adamlarının hayal gücünden etkilendiğini anladık.

PST #33 from interview: In the laboratory, we represented different society, and we need different things and we had only salty water. Our society need drinking water and we did distillation and we reached drinkable water. Our needs guide our study.

PST #33 Mülakat; Laboratuar da farklı toplumları temsil ettik ve farklı şeylere ihtiyacımız vardı ama sadece elimizde tuzlu su vardı. Bizim toplumumuz içecek suya ihtiyacımız vardı ve bizde suyu arıtarak içme suyu elde ettik. İhtiyaçlarımız bizi yönlendirdi.

PST #10 from interviews: Scientists' background knowledge can affect their creativity and their imagination.

PST #10 Mülakat; Bilim insanlarının var olan bilgileri onların hayal güçlerini ve yaratıcılılarını etkileyebilir.

PST #26 from interview: I think individual differences affect science. We draw different creatures from same fossils, because everybody has different creativity and imagination. Scientists' believes of religions and cultures can affect their imagination.

PST #26 Mülakat; Bence bireysel farklılıklar bilimi etkiler. Aynı fosil için farklı canlılar çizdik, çünkü herkes farklı hayal güçlerine sahip. Bilim insanlarının dini inançları ve kültürleri onların hayal güçlerini etkileyebilir.

PST #11 from interviews: I think experiment is very important for learning scientific knowledge. During experimentation, students can do and observe all of the process.

PST #11 Mülakat; Bence deney bilimsel bilginin öğrenilmesinde çok önemlidir. Deney süresince, öğrenciler bütün işlemleri yapabilir ve gözlemleyebilirler.

PST #28 from interviews: Learning by conducting experiments is more effective, because students can observe and can do, thus they can discover scientific knowledge like scientists.

PST #28 Mülakat; Deney yaparak öğrenme daha etkili olur, çünkü öğrenciler gözlemleyebilir ve yapabilirler. Bundan dolayı öğrenciler bilim insanları gibi bilimsel bilgiyi keşfedebilirler.

PST #8 from interviews: Experiment has main role in science. Observation and experiment are necessary for science.

PST #8 Mülakat; Deney yapma bilimde önemli bir role sahiptir. Gözlem ve deney bilim için gereklidir.

PST #4 from interview: I think observation is most important not only scientific research but also our daily life. During observation, we can understand our environment and its needs. For example, in the laboratory class, we observed the black box, then we inferred about inside the box. If we did not observe we could not infer inside the black box.

PST #4 Mülakat; Bence gözlem sadece bilimsel araştırmalar için değil aynı zamanda günlük yaşantımız içinde çok önemlidir. Gözlem yaparken çevremizi ve onun ihtiyaçlarını anlayabiliriz. Örneğin, laboratuar da kara kutuyu gözlemledik, sonrada onun içi hakkında çıkarımlarda bulunduk. Eğer kutuyu gözlemlemeseydik, kutunun içi hakkında da çıkarımda bulunamazdık.

PST #41 from interviews: During photosynthesis and germination experiments we observed all process, we observed and we did some times, thus we learned.

PST #41 Mülakat; Fotosentez ve çimlenme deneylerinde bütün süreci gözlemledik, bazen de yaptık, böylece öğrendik.

PST #45 from interviews: During experiments, we can easily understand because we can observe. In the laboratory, we did photosynthesis experiment we observed starch in leaves and we reached the results.

PST #45 Mülakat; Gözlemleyebildiğimiz için deney yaparak daha kolay anlayabiliriz. Laboratuar da fotosentez deneyini yaptık ve yapraklarda nişastayı gözlemledik, sonuca ulaştık.

PST #25 from interviews: This activity reminded me the relationship between theory and law, for one law there can be some explanations, which are accepted as theories.

PST #25 Mülakat; Bu etkinlik bana teori ve yasa arasındaki ilişkiyi hatırlattı, bir yasa için teori olarak kabul edilen birkaç tane açıklama olabilir.

PST #12 from interviews: In laboratory, we observed same thing, but our inferences about it were different. This can be related to our background knowledge or different viewpoints.

PST #12 Mülakat; Laboratuar da aynı şeyleri gözlemledik fakat bizim çıkarımlarımız farklıydı. Bu bizim var olan bilgilerimizle yada farklı görüşlerimizle ilgiliydi.

PST #18 from interviews: Every group designed different structures, because our backgrounds were different, so our inferences were different.

PST #18 Mülakat; Her grup farklı yapılar geliştirdi. Bizim var olan bilgilerimiz farklıydı bundan dolayı çıkarımlarımızda farklı oldu.

PST #29 from interviews: In laboratory, we observed a box, and then every group designed different structures. I think this is related to subjectivity, our inferences were different. After this activity, firstly I suspected reliability of scientific knowledge not at all but for some parts.

PST #29 Mülakat; Laboratuar da kutuyu gözlemledik sonra her grup farklı yapılar dizayn etti. Bence bu sübjektiflikle ilgili, bizim çıkarımlarımız farklıydı. Bu etkinlikten sonra bilimsel bilginin güvenilirliği konusunda şüpheye düştüm, bütün konular için değil ama bazıları için.

PST #3 from interviews: While doing observation we are affected from our background knowledge, according to this knowledge we observe. We observe according to our goals, we select something from other things to observe.

PST #3 Mülakat; Gözlem yaparken var olan bilgilerimizden etkilendik, ön bilgilerimize göre gözlem yaptık. Kendi amaçlarımıza göre gözlemlerimizi yaptık, gözlem yapacağımız şeyleri seçtik.

PST #14 from interviews: I understand that scientists can have different inferences about same thing. In addition, I understand that there could be different ways to reach the same conclusion.

PST #14 Mülakat; Bilim insanlarının aynı konu hakkında farklı çıkarımları olabileceğini anladım. Ayrıca aynı sonuca ulaşmak için farklı yolların olduğunu anladım.

PST #9 from reflection paper: Scientists provide many theories about a scientific knowledge, then they observe as theories, but their observations and their studies are affected by their prior theories, prior knowledge, beliefs, etc. Thus, scientists reach different conclusions. Therefore, they have different inferences.

PST #9 Mülakat; Bilim insanları bilimsel bilgi için bir çok teori ortaya koyuyorlar, sonra teorilerini gözlemliyorlar. Fakat onların gözlemleri ve çalışmaları önceki teorilerinden ve inançlarından etkileniyor. Bundan dolayı bilim insanları farklı sonuçlara ulaşıyorlar, bundan dolayı farklı çıkarımlara sahip olabiliyorlar.

PST #26 from reflection paper: Inferences are interpretations of observations and depend on our prior knowledge and experience.

PST #26 Mülakat; Çıkarımlar gözlemlerin yorumlarıdır ve ön bilgilerimize ve deneyimlerimize bağlıdır.

PST #9 from interview: I think it [Black Box] can be related to creativity, because people can have different creativities. In the past about atom, different scientists inferred different atom models.

PST #9 Mülakat; Bence kutu etkinliği yaratıcılıkla ilşkili olabilir, çünkü insanlar farklı yeteneklere sahip olabilirler. Geçmişte atom hakkında farklı bilim insanları farklı atom modelleri ortaya atmışlar.

PST #30 from interviews: Each group designed different system, all of them were right. I think this can be related to tentativeness of scientific knowledge.

PST #30 Mülakat; Her grup farklı sistemler dizayn etti, hepside doğruydu. Bence bu bilimsel bilginin değişebilirliği ile ilgili.

PST #1 from interviews: Different inferences depend on different background of people and different socio-cultural structures.

PST #1 Mülakat; Farklı çıkarımlar insanların farklı önbilgilerinden ve sosyal kültürel yapılarından kaynaklanıyor.

PST #24 from interviews: Scientists use their background knowledge and they are affected from cultural-social structure.

PST #24 Mülakat; Bilim insanları var olan bilgilerini kullanırlar ve sosyal kültürel yapıdan etkilenirler.

PST #31 from interviews: I think this [the observation-inference activity] can be related to creativity, and I saw that scientific knowledge is not absolute.

PST #31 Mülakat; Bence bu etkinlik yaratıcılıkla ilgili olabilir, benim anladığım bilimsel bilgi kesin değildir.

PST #38 from interviews: Scientific knowledge can be changed, because more people made investigations continuously using different methods and different scientists can find new things and science is developed. Imagination, religion, geographic environment, and culture affect science.

PST #38 Mülakat; Bilimsel bilgi değişebilir, çünkü birçok insan farklı metotlarla sürekli araştırma yapıyor, ve bilim insanları yeni şeyler bulup bilimi geliştirebilirler. Hayal gücü, din, çevre ve kültür bilimi etkiler.

PST #13: I liked this course, after the laboratory, I learned many new things about science. Before this course, I took some laboratory courses, but this course was different.

PST #13 Mülakat; Bu dersten hoşlandım, laboratuar dan sonra bilim hakkında birçok yeni şey öğrendim. Bu dersten önce bazı laboratuar dersleri almıştım, ama bu ders çok farklıydı.

PST #14: In this course every week, I learned different things about science and I was surprised, my old views changed.

PST #14 Mülakat; Her hafta bu derste bilim hakkında farklı şeyler öğrendim ve şaşırdım, bilim hakkındaki eski görüşlerim değişti.

PST #20: Before this course, I did not know NOS aspects. However, science has its nature from beginning; we were not taught about this subject. In this laboratory, I learned many new things about science. I liked this course.

PST #20: Bu dersten önce bilimin doğası hakkında bilgim yoktu. Bilimin özellikleri başlangıçtan beri vardı fakat bize bu konuda bir şey öğretilmedi. Bu laboratuar da bilim hakkında birçok şey öğrendim. Bu dersten hoşlandım.

PST #33: Before this semester I did not know anything about NOS, my views were changed. I knew that scientific knowledge is absolute, and it is affected from creativity. Every week I learned different things and I was surprised.

PST #33 Mülakat; Bu dönemden önce bilimin doğası hakkında hiçbir şey bilmiyordum, düşüncelerim değişti. Bilimsel bilginin şimdi kesin olmadığını biliyorum ve onun yaratıcılıktan etkilendiğini. Her hafta farklı şeyler öğrendim ve heyecanlandım.

PST #24: I took some laboratory course before, this laboratory course was different from others, because we did activities, and learned NOS very effectively. My views changed about science, I prepared lesson plans for other course, and I used some activities to teach NOS aspects. During the course after the activities there were presentations about that week aspect, I think they were very helpful for us.

PST #24 Mülakat; Daha önce bazı laboratuar dersleri almıştım, bu ders diğerlerinden farklıydı çünkü etkinlikleri biz yaptık ve bilimin doğasını etkili bir şekilde öğrendik. Bilim hakkındaki düşüncelerim değişti, başka bir ders için ders planları hazırladım ve bilimin doğasını öğretmek için bazı etkinlikleri kullandım. Laboratuar da etkinliklerden sonra bilimin doğası hakkında sunumlar vardı bence onlar bizim için çok faydalı oldu.

PST #27: Every week we focused one aspect, and my views about NOS were changed. I understand the relation between theory and law, scientists are not objective, scientific knowledge is theory-laden and it is tentativeness. Before this course, I thought scientists right 100 % of their work, and scientific knowledge absolute and not changeable.

PST #27: Her hafta bilimin doğasıyla ilgili bir özelliğine odaklandık. Teori ve yasa arasındaki ilişkiyi anladım, bilim insanlarının objektif olmadıklarını, bilimsel bilginin teori temelli olduğunu ve değişebilir olduğunu. Bu dersten önce bilim insanlarının % 100 doğru olduklarını, bilimsel bilginin kesin olduğunu ve değişmeyeceğini düşünüyordum.

PST #3: Actually, I liked this laboratory course. I think NOS can be taught in laboratory better. I prefer laboratory to teach NOS. Because of students can learn doing and seeing. For example, I learned NOS in this course, and I used my NOS views for other courses. I took same laboratory courses before, we only observed something and we go out without doing anything, thus we did not learn anything. Before this course I did not know anything about NOS. I think students firstly may learn NOS then learn other science context. We separated science from society, we learned in the past only scientists do science. However, today science affects every people daily life, and firstly students should learn NOS. Thus, learning NOS directly related to scientific literacy. After this course, my views about scientific knowledge completely changed.

PST #3: Bu laboratuar dersini sevdim. Bence bilimin doğası laboratuar da daha iyi öğretilebilir. Ben bilimin doğasını öğretmek için laboratuarı tercih ederim. Çünkü öğrenciler yaparak ve görerek öğrenebilirler. Mesela, ben bilimin doğasını bu derste öğrendim ve bu bilgilerimi farklı derslerde kullandım. Daha öncede laboratuar dersleri almıştım ama biz sadece gözlemliyorduk sonrada hiçbir şey yapmadan çıkıp gidiyorduk, bundan dolayı hiçbir şey öğrenmedik. Bu dersten önce bilimin doğası hakkında hiçbir şey bilmiyordum. Bence öğrenciler ilk olarak bilimin doğasını öğrenmeliler sonrada diğer fen konularını. Bilimle toplumu birbirinden ayırmışız, geçmişte bilimi sadece bilim adamlarının yapabileceğini öğrenmiştik. Fakat bugün bilim bütün insanların günlük yaşantısını etkiliyor bundan dolayı öğrenciler bilimin doğasını öğrenmeliler. Çünkü bilimin doğasını öğrenmek bilim okuryazarlığı ile direk ilişkili. Bu dersten sonra bilim hakkındaki düşüncelerim tamamıyla değişti.

PST #34: Firstly, I understand NOS in this semester. I think NOS is complex, my views about NOS were changed. Sometimes only listening or reading is not enough to understand, thus I prefer laboratory activities to teach NOS. My old readings about NOS aspects were meaningful in this laboratory course. Unfortunately, up this time, I went to best schools but I had many misconceptions about nature of science. Now, I changed my views thus I am happy. In the laboratory there were some discussions, these were important I learned many things. Every week we wrote reflection papers about NOS and SPS, I think these papers helped us to understand NOS and SPS concepts. This course was the best laboratory course for me and I know for many friends. I will be a science teacher I will use these activities.

PST #34: Bilimin doğasını bu dönem anladım. Bence bilimin doğası karmaşık bir konu ve benim bilimin doğası hakkındaki düşüncelerim değişti. Bazen sadece dinlemek veya okumak anlamak için yeterli olmuyor, bundan dolayı bilimin doğasını öğretmek için laboratuar etkinliklerini tercih ederim. Bilimin doğası hakkındaki önceki okumalarım bu laboratuar dersinde anlamlı hale geldi. Maalesef bu zamana kadar çok iyi okullarda okumama rağmen bilimin doğası halında birçok yanlış kavramlarım vardı. Şimdi hepsi değişti ve bu beni mutlu ediyor. Laboratuar da tartışma ortamları vardı ve ben bunlardan çok şey öğrendim. Her hafta bilimin doğası ve bilimsel süreç becerileri hakkındaki düşüncelerimizi yazdık. Bence bu yazılar kendi anlayışımızda bize yardım etti. Bu ders benim ve birçok arkadaşım için aldığımız en iyi laboratuar dersi oldu. İlerde bende öğretmen olacağım ve bu etkinlikleri kullanacağım.

PST #20: After activities, the instructor made presentation and we discussed about NOS views, thus we understood easily.

PST #20: Etkinliklerden sonra hocamız sunum yaptı ve bizde tartıştık, bundan dolayı bilimin doğasını kolayca anladık.

Part #34: Before this semester, I had some misconceptions, such as theories become laws, and laws cannot be changed. At the end of the activity, there was a presentation in the laboratory, we discussed these concepts, and our misconceptions were changed.

Part #34: Bu dönemden önce bazı kavram yanılgılarım vardı mesela, teorilerin yasaya dönüşeceği ve yasaların değişemeyeceği gibi. Etkinliğin sonunda sunum vardı ve kavramlar hakkında tartıştık bunlardan dolayı kavram yanılgılarımızı giderdik.

PST #4: During the activities, we discussed our group members, and at the end, we reached scientific knowledge. In addition, there were presentations after the activities, we learned and connect NOS aspects with these activities.

PST #4: Etkinlikleri yaparken grup arkadaşlarımızla tartıştık ve sonunda bilimsel bilgilere ulaştık. Buna ek olarak etkinliklerden sonra sunumlar vardı, bilimin doğasına yönelik anlayışımız gelişti ve bu etkinliklerle bilimin doğasını öğrendik.

PST #2: I think there are relationships among NOS, SPS and scientific knowledge. While doing experiment we use SPS, using SPS help us to study more systematic, it would be different methods in science. We can reach some results with different methods. We used SPS doing activities in laboratory.

PST #2: Bence bilimin doğası bilimsel süreç becerileri ve bilimsel bilgi arasında bir ilişki vardır. Deneyleri yaparken biz bilimsel süreç becerilerini kullandık, buda bizim daha sistematik olmamıza yardımcı oldu, bilimde farklı metotlarda olabilir. Sonuca farklı metotlarla ulaşabiliriz. Bilimsel süreç becerilerini kullanarak laboratuar etkinliklerini yaptık.

PST #27: There is strong relationship among scientific knowledge, SPS, and NOS. I figure out that there is a destination we want to reach it, this is scientific knowledge, we used some tools which are SPS and scientific methods, and our way of this journey is NOS.

PST #27: Bilimin doğası, bilimsel süreç becerileri ve bilimsel bilginin arasında çok sıkı bir ilişki vardır. Ben bilimsel bilgiyi ulaşmak istediğimiz bir durağa benzetiyorum, bu yolda bilimsel süreç becerileri de kullandığımız araçlar ve yolun kendini de bilimin doğasına benzetiyorum.

PST #6: We cannot separate NOS and SPS. Because, in order to do activity we used many SPS in laboratory, and at the end we constructed our scientific knowledge. We should do these to develop science, and findings should be shared by other peoples to develop science.

PST #6: Bilimin doğasını ve bilimsel süreç becerilerini birbirinden ayıramayız. Çünkü etkinlikleri yapmak için laboratuar da birçok süreç becerisini kullandık, sonunda kendimizin bilimsel bilgisini oluşturduk. Bilimin gelişmesi için bunları yapmalıyız ve sonuçları diğer insanlarla paylaşmalıyız.

PST #31: I think laboratory is more suitable to learn not only NOS aspects but also other science context. Because in laboratory we are active, we do, thus we learn better than traditional class presentations.

PST #31: Bence laboratuar sadece bilimin doğası için değil diğer fen konuları içinde çok uygun bir öğrenme ortamı. Çünkü biz laboratuar da yapıyoruz bundan dolayı geleneksel hoca anlatımından daha iyi öğreniyoruz.

PST #37: Firstly, I liked this course, I read laboratory manual before and we did activities ourselves, thus we could easily understand NOS aspects.

PST #37: Ben bu dersi sevdim, dersten önce laboratuar formunu okudum ve etkinlikleri kendimiz yaptık, bundan dolayı bilimin doğasını kolaylıkla anladık.

PST #40: I think student do not understand NOS aspect in class by direct teaching. I remember all of things in the laboratory, because first, we were in conflict then we do activities and we understood. In addition, until the laboratory course I did not set up any experiment, in this course we designed experiments.

PST #40: Bence öğrenciler sınıfta direk anlatımla bilimin doğasını anlayamazlar. Laboratuardaki her şeyi hatırlıyorum, çünkü ilk olarak ilkeme düşüyorduk sonra etkinliği yapıyorduk sonrada anlıyorduk. Ayrıca, bu derse kadar hiç deney düzeneği kurmamıştım, bu derste deneyleri biz tasarladık.

Part #12: I do not think NOS can be taught in class with only lecture. Especially in elementary school, students cannot understand NOS views without laboratory. I think laboratory is important for science courses. I prefer laboratory to teach NOS aspects. Students should do experiments, they should observe directly. My views about NOS were changed during the laboratory course, if I did not join this course, I will graduated from university, I will be a teacher and unfortunately I will teach to my students wrong things about NOS.

Part #12: Bilimin doğasının sınıfta anlatımla öğretilebileceğini düşünmüyorum. Özellikle ilköğretim okullarında öğrenciler laboratuar dersi olmadan bilimin doğasını anlayamazlar. Bence laboratuar fen dersleri için önemlidir. Ben bilimin doğasını öğretmek için laboratuarı tercih ederim. Öğrenciler deney yapmalılar ve direk gözlem yapmalılar. Bilimin doğası hakkındaki görüşlerim bu dersten sonra değişti, eğer bu dersi almamış olsaydım buradan mezun olup fen bilgisi öğretmeni olacaktım ve öğrencilerime yanlış şeyleri öğretecektim.

PST #17: When I will be a teacher, I will use laboratory for teaching NOS aspects. Because, I think elementary students could not understand NOS aspect with oral conservations. Students need activities about NOS. In this course, we did activities and we learned better, also we will be teachers, and we will teach NOS like that.

PST #17: Fen bilgisi öğretmeni olduğum zaman bilimin doğasını öğretmek için laboratuarı kullanacağım. Çünkü ilköğretim öğrencileri sözlü anlatımla bilimin doğasını anlayamazlar. Öğrencilerin bilimin doğası hakkında etkinliklere ihtiyaçları var. Bu derste biz etkinlikleri yaptık ve daha iyi öğrendik. Ayrıca biz öğretmen olacağız ve ilerde bilimin doğasını böyle öğreteceğiz.

PST #19: This laboratory is different other laboratory courses. I think not only NOS but also other science classes should be taught in laboratory. I remember when I was a high school, only I memorized scientific knowledge in class during lectures, them I forgot them. I learn better in laboratory, because I observe, and I do experiments. I will use some activities from this course, when I will be science teacher.

PST #19: Bu laboratuar diğer laboratuar derslerinden farklı. Bence sadece bilimin doğası değil diğer fen dersleri de laboratuarda öğretilmeli. Lisedeyken anlatılan fen derslerini sadece ezberliyordum sonrada unutuyordum. Laboratuar da daha iyi öğrenirim çünkü gözlemleyebilirim ve deneyleri kendim yapabilirim. Fen bilgisi öğretmeni olduğum zaman bu derste öğrendiğim bazı etkinlikleri bende kullanacağım.

PST #25: This laboratory course was different other laboratories. I think for teaching many aspects laboratory environment is useful, because students can learner better doing activities. However, some of them can be taught in class. I think laboratory should be fruitful, students should like laboratory environments. I will use similar activities to teach NOS aspect for my students in future.

PST #25: Bu laboratuar dersi diğer laboratuar derslerinden farklıydı. Bence bilimin doğasında bir çok aspect için laboratuar ortamı faydalıdır çünkü öğrenciler yaparak daha iyi öğrenirler. Fakat bazıları da fen dersinde sınıf ortamında öğretilebilir. Bence laboratuar dersleri eğlenceli olmalı, öğrenciler dersten hoşlanmalılar. Gelecekte kendi öğrencilerime bilimin doğasını öğretmek için benzer etkinlikleri kullanacağım.

PST #29: I prefer laboratory environment to teach NOS aspects. I think if students do something they can learn better. Science classes should be student centered, students should observe, thus they like science, otherwise science classes are boring for students. Moreover, during activities students can use and develop their creativities.

PST #29: Bilimin doğasını öğretmek için laboratuar ortamını tercih ederim. Bence eğer öğrenciler bir şeyler yaparlarsa daha iyi öğrenirler. Fen dersleri öğrenci merkezli olmalıdır, öğrenciler gözlem yapmalılar böylece fenden hoşlanırlar yoksa fen dersleri öğrenciler için sıkıcı oluyor. Ayrıca etkinlikleri yaparken öğrenciler kendi yeteneklerini kullanabilir ve geliştirebilirler.

PST #7: I absolutely believe that application is very important in science, because after practice scientific knowledge will be more lasting and fruitful for students. I think science lesson should be taught with inquiry methods in laboratory. Students should do experiments. If students do experiment, they can learn better. Lecture is not enough for learning, because students memorize after lecture.

PST #7: Bence fende öğrencinin katılımı çok önemli, çünkü pratik yaptıktan sonra bilimsel bilgi öğrenciler için daha kalıcı oluyor. Bence fen dersleri laboratuarda araştırmaya dayalı yöntemlerle öğretilmeli. Öğrenciler deney yapmalılar, eğer böyle yaparlarsa daha iyi öğrenebilirler. Doğrudan anlatım öğrenme için yeterli değil, çünkü öğrenciler anlatımdan sonra sadece ezberliyorlar.

PST #8: I do not think class is suitable for science education, I prefer laboratory. Because in class we listen to teachers, take note, and memorize scientific knowledge, after exams we forget all of them. Especially, NOS should be taught in laboratory, because in laboratory, students do experiment, and they can have concrete data, thus they can learn better.

PST #8: Fen eğitimi için sınıf içinin uygun olduğunu düşünmüyorum, ben laboratuarını tercih ederim. Çünkü sınıfta sadece hocayı dinleriz, not alırız, bilgileri ezberleriz sınavdan sonrada hepsini unuturuz. Özellikle bilimin doğası laboratuarda öğretilmeli çünkü laboratuarda öğrenciler deney yapar kendi verilerini oluşturur bundan dolayı daha iyi öğrenirler.

Appendix H

Consent Form

Öğrenci Gönüllü Katılım Formu

Bu çalışma daha önce de belirtildiği gibi ODTÜ ilköğretim bölümü öğretim üyelerinden Yard. Doç. Dr. Özgül Yılmaz-Tüzün yöneticiliğinde yürütülen araştırma görevlisi Sinan Özgelen'in tez çalışmasıdır. Bu çalışmanın amacı eğitim fakültesinde öğrenim gören fen bilgisi öğretmen adaylarının bilimin doğası hakkındaki görüşlerinin belirlenmesi geliştirilmesidir. Bu amacı gerçekleştirmek için fen bilgisi laboratuarında en uygun metotlardan biri olan araştırma yöntemi kullanılacaktır. Bu çalışmaya katılım tamamen gönüllülük temeline dayalıdır. Yapılacak uygulamalarda sizden kimlik belirleyici hiçbir bilgi istenmeyecektir. Cevaplarınız tamamıyla gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecektir. Elde edilecek bulgular bilimsel yayımlarda kullanılacaktır.

Uygulamalar genel olarak kişisel rahatsızlık verecek soruları içermemektedir. Ancak, katılım sırasında sorulardan ya da herhangi başka bir nedenden ötürü kendinizi rahatsız hissederseniz katılım sürecini yarıda bırakabilirsiniz. Böyle bir durumda araştırmacıyı haberdar etmeniz yeterli olacaktır. Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz. Çalışma hakkında daha fazla bilgi almak için Sinan Özgelen (Tel: 210 4053; email; sozgelen@metu.edu.tr) ile iletişim kurabilirsiniz.

Bu çalışmaya tamamen gönüllü olarak katılıyorum ve istediğim zaman yarıda bırakabileceğimi biliyorum. Verdiğim bilgilerin bilimsel amaçlı yayımlarda kullanılmasını kabul ediyorum. (Formu doldurup imzaladıktan sonra uygulayıcıya geri veriniz).

Adı & Soyadı   Tarih   İmza   Alınan ders

Appendix I

Extended Turkish Abstract

(Genişletilmiş Türkçe Özet)

FEN BİLGİSİ ÖĞRETMEN ADAYLARININ BİLİMİN DOĞASINA YÖNELİK GÖRÜŞLERİNİN GELİŞİMİNİN SORGULAYICI ÖĞRETİME DAYALI LABORATUAR DERSİNDE İNCELENMESİ

Giriş

Bilimin doğasının (Nature of science) anlaşılması bilim okuryazarlığının (Scientific literacy) temel bir yapıtaşı olarak kabul edilir. Bundan dolayı fen alanındaki birçok reform çalışması bilimin doğasının öğrenciler tarafından anlaşılmasını bir hedef olarak belirlemiştir. Bilimin doğasına ait kavramların öğrencilere kazandırılması eğitimciler tarafından amaçlanmasına rağmen tanımı konusunda tam bir uzlaşı yoktur. Bu çalışmada bilimin doğası bilimsel bilginin kendinden kaynaklanan değerleri ve varsayımları içerir ve bilimin bir insan ürünü olması nedeniyle dış faktörlerden etkilendiğini kabul eder. Bu çalışmada bilimsel bilginin yedi temel karakteristik özelliği üzerinde durulmuştur. Bunlar; değişebilir olma (tentativeness), deney temelli olma (empirical based), sübjektif olma (subjectivity), hayal gücünden ve yaratıcılıktan etkilenme (creativity), toplumdan ve kültürden etkilenme (socio-cutural embedded) ve son ikisi gözlem-çıkarım (observation and inference) ve teori-yasa (theory and law) kavramları arasındaki ilişkilerin ortaya konulmasıdır. Bilimin doğası hakkında geçmiş çalışmaları derleyen araştırmacılar birçok fen öğretmeninin ve öğrencinin bilimin doğasına yönelik kavram yanılgılarının olduğunu ortaya çıkarmıştır. Bilim okuryazarlığının diğer önemli bir yapıtaşı bilimsel araştırma yöntemidir (Scientific inquiry), oda bilimsel bilginin gelişimi için onu yönlendiren metotlar ve bilimsel araştırmanın özelliklerini içerir. Bilimsel süreç becerileri (scientific process skills) ile bilimsel bilginin birlikte kullanılmasıyla bilimsel araştırma tam olarak uygulanmış olur. Öğrencilerin bilimin doğası hakkında görüşlerini belirlemek ve onları geliştirmek için yapılan çalışmalar genellikle fen öğretimi (metot) derslerinde yapılmıştır. Fen laboratuarı bunun için uygun olduğu halde bu zamana kadar çok kullanılmamıştır. Fen öğretimi için yapılan konferanslarda ve toplantılarda araştırmaya dayalı laboratuar yöntemi ısrarla tavsiye edilmiştir. Bu sayede öğrencilerin hem bilimsel okuryazarlıları hem de bilimim doğasına yinelik anlayışlarının gelişebileceği vurgulanmıştır. Bu çalışmada fen bilgisi laboratuar uygulamaları dersinde yapılmıştır.

Fen literatürdeki çalışmalar göstermiştir ki öğretmen adayları ve öğretmenlerin bir çoğu bilimin doğası hakkında kavram yanılgılarına sahipler. Bu ciddi bir problem çünkü eğer öğretmenler kavram yanılgılarına sahiplerse bunları kendi dersleri yoluyla öğrencilerine de geçebilirler. Yapılan çalışmalar göstermiştir ki öğretmenin sınıf içindeki bütün davranışları öğrencilerin öğrenmesinde etkilidir ve öğrencilerin öğrenmeleri öğretmenden bağımsız değildir. Bilimin doğasının amaçlandığı gibi öğretilmesi için öncelikle fen öğretmenlerinin bilimin doğasını doğru bir şekilde anlamış olması gerekmektedir buda onların üniversitedeki eğitimleri boyunca uygun deneyimler sayesinde kazandırılabilir. Fen eğitimindeki önemli reformlardan sonra birçok ülke bilimin doğasına fen müfredatlarında işledi. Bu ülkelerden biride Türkiye'dir, ilköğretim fen bilgisi ders programı yeniden tasarlanıp bilimin doğasına yönelik amaçlar müfredata konuldu. Yeni fen programı kişisel farklılıkları ne olursa olsun bütün öğrenciler için bilim okuryazarlığını hedeflemiştir. Bu bağlamda yeni program bilimin doğasının tam olarak anlaşılmasını ana hedeflerinden biri olarak belirlemiştir. Yapılan araştırmalarda öğrencilerin bilimin doğasına yönelik anlayışlarının gelişmesinde öğretmenlerin çok etili bir faktör olduğu ortaya konulmuştur. Eğer fen öğretmenleri bilimin doğasını anlamaz ve bunu öğretmenin neden önemli olduğunu kabul etmez iseler Türkiye'de oluşturulan bu yeni müfredatı derslerinde uygulamayacaklardır. Eğer öğretmenler bu programı uygulamazsa yeni müfredat değerini ve önemini yitirmiş olacaktır. Bu çalışmanın örneklemi fen bilgisi öğretmen adaylarıdır yanı geleceğin fen bilgisi öğretmenleri. Bu çalışmanın amacı ilköğretim fen bilgisi öğretmen adaylarının bilimin doğasına yönelik görüşlerinin doğrudan-yansıtıcı ve araştırmaya dayalı laboratuar öğretimiyle gelişiminin incelenmesi ve öğretmen adaylarının bilimin doğasıyla ilgili olarak algıları ve deneyimlerinin neler olduğunun araştırılmasıdır.

Metot

Bu çalışma Fen Bilgisinde Laboratuar Uygulamaları II dersinde yapılmıştır. Toplam 52 fen bilgisi öğretmen adayından 45 tanesi (34 kız ve 11 erkek) bu çalışmaya gönüllü olarak katılmayı kabul etmiştir. Öğretmen adaylarını hepsi üçüncü sınıf fen bilgisi öğrencisidir. Bu ders 2008'in bahar dönemimde iki farklı sınıf olarak uygulandı. İlk sınıf 27 öğretmen adayından oluşuyordu ve Salı günleri haftada bir kez dört saat olarak laboratuarda ders yapılıyordu. İkinci grup 25 kişiden oluşuyordu onlarda Perşembe günleri aynı laboratuarda ders yapıyorlardı. Laboratuar derslerinde öğrenciler kendi oluşturdukları gruplarla çalışmalarını yaptılar. Çalışma araştırmacı tarafından koordine edildi ve iki doktora öğrencisi tarafından uygulandı. Bu çalışmada öğretmen adaylarının bilimin doğasına yönelik anlayışlarının gelişimini tespit etmek için nitel araştırma yöntemi kullanılmıştır. Çalışmanın başlangıcında öğretmen adaylarının bilimin doğasına yönelik görüşlerini belirlemek için açık uçlu sorular kullanılarak veri toplanmıştır. Bunun için *Views of Nature of Science Questionnaire Version B* (VNOS-B) ölçeği uygulandı, bu ölçek Lederman, Abd-El-Khalick, Bell, ve Schwartz (2002) tarafından geliştirilmiş. Çalışma boyunca her hafta öğretmen adaylarının deneyimlerinin anlaşılması ve bilimin doğası hakkındaki gelişimlerinin belirlenmesi için yazılı dokümanlar toplandı. Dönemin sonunda doğrudan-yansıtıcı ve araştırmaya dayalı laboratuar öğretiminin etkisini belirlemek için öğretmen adaylarıyla mülakat yapıldı ve *Views of Nature of Science Questionnaire Version B* (VNOS-B) ölçeği yeniden uygulandı. Toplanan veriler çalışma bittikten sonra NVivo yazılım programına yüklendi ve analizler yapıldı.

Bulgular

Bu kısımda bütün veriler analiz edildi ve özet şeklinde verildi. Araştırmanın ilk sorusu laboratuar etkinlikleriyle bilimsel bilginin karakteristik özellikleri arasında bağlantıların kurulmasıyla ilgili bir alt araştırma sorusunu içerir. Bu çalışmada öğretmen adaylarının bilimin doğasına yönelik anlayışlarını geliştirmek için bazı laboratuar etkinlikleri geliştirilmiş ve sonunda öğrencilerin bu etkinliklerle bilimin doğasını nasıl ilişkilendirdikleri araştırılmıştır.

Laboratuardaki ilk iki etkinlik bilimsel bilginin deney temelli olmasıyla ilgiliydi. Bütün öğretmen adayları yapılan etkinliklerle bilimsel bilginin deney temelli olması arasında bir ilişki kurmuşlardır. Örneğin bir öğretmen adayı bilimsel bilginin neden deney temelli olduğunu ve bununda nasıl bilimsel bilginin güvenirliği ile ilgili olduğunu aşağıdaki alıntıda belirtmiştir;

> PST #16 (Fen Bilgisi öğretmen adayı, numara 16, mülakat): Kesinlikle deneyin önemi var, deneysiz gözlemsiz bilimsel bilgiye ulaşmak zor olur. Bir şeyin gerçekliğini anlatmak için sebep-sonuç ilişkisini dolayısıyla deneylere ihtiyacımız vardır. Deneyler bilimsel bilgiye ulaşmada ilk adımdır. Deneylerin sonuçları insanlara göre değişmez, buda bilginin güvenilir olmasını sağlar.

Fen laboratuarındaki ikinci etkinlik gözlem ve çıkarım arasındaki farkı ve aralarındaki ilişkiyi bilimsel bilgi açısından ortaya koymak için tasarlanmıştır. Araştırmanın sonunda bütün katılımcıların bu etkinlikle gözlem ve çıkarım arasındaki ilişkiyi belirttiği belirlenmiştir. Aşağıda öğrencilerin bu konuda belirttiği ifadelerden bir kaçı örnek olarak verilmiştir.

> PST #35 Mülakat; Laboratuarda direk olarak kutuyu gözlemledik ve yorumumuzu katmadan gözlemlerimizi kaydettik. Çıkarım için kutunun içindeki sistemi keşfetmeye çalıştık. Laboratuarda gözlemlerimiz aynıydı fakat çıkarımlarımız farklıydı.

> PST #32 Mülakat; Özellikle bazı konularda çıkarım yapmak zorundayız, mesela atom hakkında, evren hakkında ya da evrim konularında deney yapabilmemiz mümkün değildir. Bu tür konuları açıklamak için çıkarımlar yoluyla modeller oluşturulur. Laboratuarda biz kutuyu gözlemledik, içini görmemiz mümkün değildi, bundan dolayı bazı çıkarımlar yaptık, bence bu önemliydi.

Bu alıntılarda öğretmen adayları gözlem ve çıkarım arasındaki farkı vurgulamışlardır, bütün gruplar birbirine yakın gözlemlerde bulunmuşken her grup çok farklı çıkarımlarda bulunmuştur. Bazı katılımcılarda çıkarım ve bilim insanların yaptığı modeller arasında ilişki kurmuşlardır.Bilim insanları doğal olayları açıklayabilmek için modeller ortaya koyarlar. Özellikle bazı konularda deney düzeneği kurulmayacağı için bilim insanlarının modelleri doğa olaylarını açıklamada önemli bir yere sahiptirler. Örneğin bir öğretmen adayı bunu şöyle ifade etmiştir;

PST #13 Mülakat; Laboratuarda kutunun içini görmedik sadece çıkarım yaptık. Bilim insanlarının görülemeyen şeyle hakkında çıkarım yapıp bilimsel bilgiye ulaşabildiklerini anladım. Aynı şeyi gözlemledik fakat farklı çıkarımlarımız oldu.

Fen laboratuarındaki üçüncü etkinlik teori ve yasa arasındaki farkı ve aralarındaki ilişkiyi bilimsel bilgi açısından ortaya koymak için tasarlanmıştır. Özellikle birçok öğretmen adayında teori ve yasa arasında hiyerarşik bir ilişki olduğu kavram yanılgısı ortaya çıkarılmıştır. Bu etkinlikten sonra bir çoğu bu kavram yanılgısını gidermişlerdir. Aşağıda bir öğretmen adayının bu konuda belirttiği ifade verilmiştir.

PST #38 Mülakat; Bu etkinlikten önce teorilerin yasalara dönüşeceğini ve yasaların değişmeyeceğini düşünüyordum, çünkü bunlar bize böyle öğretildi, laboratuardaki herkes bu tür yanlış kavramlara sahipti. Fen kitaplarında bununla ilgili grafikler vardı [hipotezden yasaya dikey ilişkiyi gösteriyordu], bunsan dolayı bizler yanlış öğrendik.

Dönem sonunda bütün katılımcıların bu etkinlikle teori ve yasa arasında ilişki kurduğu belirlenmiştir. Aşağıda bir öğretmen adayından bir alıntı yapılmıştır.

PST #10 Mülakat; Bu laboratuar da biz Boyle-Mariotte yasasını kullandık, ve bir etkinlik dizayn ettik. Basınç ve hacim arasındaki ilişkiyi göstermek için moleküler kinetik teoriyi kullandık. Teoriler yasaları açıklamaya çalışır.

Laboratuardaki dördüncü etkinlik bilimsel bilginin sübjektif olduğunu anlamaya yönelik tasarlanmış bir etkinliktir. Çalışmanın sonuçlarına göre fen bilgisi öğretmen adaylarının tümü bu etkinlikle bilimsel bilginin sübjektif olmasını ilişkilendirmişlerdir. Öğretmen adayları var olan teorilerin bilim insanlarının çalışmalarını etkilediklerinin belirtmişlerdir. Aşağıda bununla ilgili öğretmen adaylarından alıntılar verilmiştir.

> PST #1 Mülakat; Bence bilim insanları araştırma yaparken var olan teorilerden etkilenirler. Laboratuar da kendi teorimize göre bazı hipotezler geliştirdik. Farklı gruplar farklı teorilerden dolayı farklı hipotezler kurdular. Sonuçta, her grup aynı veriden farklı sonuçlara ulaştı, fakat bütün bu farklı sonuçlar kabul edilebilirdi.

> PST #15 Mülakat; Laboratuar da bize DNA molekülleri ve iki farklı evrim teorisi verildi. Bütün gruplar aynı veriye sahipti, fakat sonunda herkes farklı hipotezleri destekledi. Bilimsel bilginin var olan teorilerden etkilendiğini anladım. Teoriler araştırmaları yönlendirebilir. Bu etkinlikte kendi teorimize göre hipotezler kurduk.

> PST #21 Mülakat; Bence bilimsel araştırma yapılırken bilim insanlarının var olan teorilerden etkilenmesi normaldir. Bu etkinlikte biz aynı veriyi kullandık ama farklı teorilerimiz vardı, sonuçlarımız farklı oldu. Beklentilerimiz bizim teorilerimizden etkilendi. Bilim insanları aynı veriden farklı sonuçlara ulaşabilirler. Bilimin objektif değil sübjektif olduğunu anladım. Özellikle bazı konular var ki çok tartışmalı mesela evrim.

Fen bilgisi öğretmen adayları var olan teorilerin bilimsel çalışmalar üzerindeki etkisinin farkın varmışlardır, laboratuardaki deneyimlerinden örnekler vermişlerdir. Sonuç olarak bilim insanlarının farklı teorilerden dolayı aynı veriden farklı sonuçlara ulaşabileceklerini belirtmişlerdir.

Bazı öğretmen adayları bilim insanlarının farklı teorileri benimseyip onlarla çalışmalarını, bilim insanlarının kişisel tercihleriyle ilgili olduğunu bununda bilimi etkilediğini belirtmişlerdir. Örnek olarak aşağıda bir öğretmen adayından alıntı verilmiştir.

> PST #27 Mülakat; Laboratuar da aynı verileri kullanarak farklı teorileri destekledik. Bilim insanlarının kendi amaçlarına göre bilimsel verileri kullanabileceklerini anladım. Bence, bu bilimin sübjektif olmasıyla alakalı. Bilim insanları günümüzdeki verileri analiz etmek için geçmişteki teorileri kullanırlar. Eğer bir konu hakkında farklı teoriler varsa, bilim insani geçmiş bilgilerine ya da inançlarına bağlı olarak içlerinden birini seçebilir. Mesela bazı bilim insanları türlerin kökeni olarak evrim teorisini desteklerken bazıları da yaratıcılığı desteklemektedirler. Bu tartışmalı bir konu, bence bilim insanları objektif değiller.

Bazı öğretmen adayları da bilim insanının farklı teorileri takip etmesinin farklı nedenlerden dolayı kaynaklanabileceğini iddia etmişlerdir. Mesela var olan bilgilerinin, kültürün. Aşağıda bir öğretmen adayından alıntı verilmiştir.

> PST #23 Mülakat; Bilim insanlarının kendi kültürlerine ve önceki bilgilerine bağlı olarak farklı teorilerden etkilendiklerini anlıyorum. Mesela dinozorların yok oluşuyla ilgili bilim adamlarının destekledikleri farklı teoriler var.

Fen laboratuarındaki beşinci etkinlik bilimsel bilginin değişebilir olmasıyla ilgilidir. Bilimsel bilginin kesin ve değişmez bilgi olmadığı her zaman yeni bilgilerle değişime acık olduğu vurgulanmıştır. Dönemin sonunda bütün öğrenciler bilimsel bilginin sübjektif olduğu ve bu etkinlikte bu özelliğin vurgulandığını belirtmişlerdir. Aşağıda iki öğretmen adayının bu konudaki düşünceleri verilmiştir.

> PST #11 Mülakat; Bilimsel bilgi değişebilir, geçmişte değişmiştir. Laboratuar da kendi bilgimizi ve yaratıcılığımızı kullanarak fosilleri sıraladık. Yeni bilgiler geldikçe var olan sıralamayı değiştirdik. Fakat bu değişebilir olma bilimsel bilginin önemsiz olduğu anlamına gelmez, günümüzde kullandığımız bilgiler gelecekte değişebilir.

PST #40 Mülakat; Bilimsel bilgi zamanla değişebilir. Yeni bilgi var olanı değiştirebilir. Bilimsel bilgi kesin ve sabit değildir, değişime açıktır. Laboratuar da fosilleri gözlemledik ve sıraladık, yeni bilgi geldiğinde sıralamamızı değiştirdi.

Bu öğretmen adayları bilimsel bilginin değişebilir olduğunu vurgulamışlardır. Yeni yorumların ve yeni çıkarımların var olan bilimsel bilgiyi değiştirebileceklerini belirtmişlerdir.

Bazı öğretmen adayları bilimsel bilginin değişebilir olmasıyla bilimin gelişmesi arasında bir ilişki kurmuşlardır. Katılımcılar bilimsel bilgi değişebilir olmasaydı hep aynı yerinde kalacağını ve gelişimin olmayacağını ifade etmişlerdir.

PST #7 Mülakat; Bilimsel bilgi değişebilir, fakat bu bilimsel bilgi için bir eksiklik değildir. Bilimde kesin bilgi yoktur, bundan dolayı yeni bilgiler her zaman var olanı değiştirebilir ve buda bilimi geliştirir.

PST #3 Mülakat; Bence bilim sürekli olarak değişir. Bilimin değişmesi yavaştır ama değişim devam eder. Geçmişte insanların yaptığı şeyler bugün değişti, yarın da bizim bilgilerimiz değişecek ve böylece bilim gelişecek. Her şey değişebilir.

PST #4 Mülakat; Bence bilimsel bilgi değişmelidir, çünkü onun değişmesi gelişime neden olur. Eğer biz bilimsel bilginin değişmeyeceğini kabul edersek, hiç kimse onu geliştirmek için caba harcamaz. Fakat biz onun değişebilir olduğunu kabul edersek, insanlar yeni bir şeyler bulmak için sürekli olarak araştırmaya devam ederler. Ayrıca bilim doğayla ilişkilidir ve doğada sürekli olarak değişiyor, bundan dolayı bilimde değişmelidir, değişim gelişimi sağlar.

Öğretmen adayları bilimin gelişmesinde değişebilir olmasına vurgu yapmışlardır ve buradaki temel espriyi anlamışlardır. Bilimsel bilginin değişebilir olması onun bir zayıf yönü değildir aksine bilimin gelişmesini sağlar.

Fen laboratuarındaki altıncı etkinlik hayal gücü ve yaratıcılığın bilimsel bilgiyle olan ilişkisini anlatmak için geliştirildi. Bu etkinlikle bilimsel bilginin oluşturulmasında hayal gücünün ve yaratıcılığın ne kadar etkili olduğu vurgulanmıştır. Öğretmen adayları hayal gücü ve yaratıcılığın bilimsel bilginin gelişimi için ne kadar önemli olduğunun farkına varmışlardır. Aşağıda öğretmen adaylarının ifadeleri verilmiştir.

> PST #28 Mülakat; Laboratuar da aynı fosil parçaları için farklı canlılar çizdik. Bilimin bilim insanlarının hayal gücünden ve yaratıcılığından etkileneceğini anladım. Bence bazı teoriler yaratıcılığın bir ürünüdür; mesela rölativistlik teori.
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> PST #43 Mülakat; Aynı fosil parçaları için farklı canlılar çizdik, çünkü bizim hayal gücümüz ve yaratıcılığımız farklı. Bence bilim insanları kendi hayal güçlerinden etkilenirler, çünkü onlar da bizim gibi insanlar.
>
> PST# 13 Mülakat; Bence bilim insanlarının hayal güçleri ve yaratıcılıkları bilimsel bilgiyi etkiler. Laboratuar da bazı arkadaşlar ve bende aynı fosil parçası vardı, fakat bizim çizimlerimiz hayal güçlerimizin farklılığından dolayı farklıydı. Arkadaşlarımın farklı çizimlerini gördüm.
>
> PST #5 Mülakat; Laboratuar da biz aynı fosil parçalarına sahiptik, fakat herkes farklı şeyler çizdi. Çünkü herkes farklı hayal güçlerine sahiptir. Bundan dolayı hayal gücü ve yaratıcılık bizim çizimlerimizi etkiledi. Bilimin bilim adamlarının hayal gücünden etkilendiğini anladık.

Yukarıda verilen alıntılarda öğretmen adayı laboratuarda yapılan etkinlikten örnekler vererek hayal gücü ve yaratıcılığın bilimsel bilgiye nasıl etki ettiğini belirtmişlerdir. Ayrıca farklı insanların farklı hayal gücü ve yaratıcılıkları olduğundan bahsetmişlerdir.

Fen laboratuarındaki yedinci etkinlik toplum ve kültürün bilimsel bilgiye olan etkisiyle ilişkilidir. Bu etkinlikte bilimin toplumu nasıl etkilendiği ve toplumdan nasıl etkilendiği araştırılmıştır. Öğretmen adaylarının tamamın yakını sosyal faktörlerin bilimsel bilgiyi etkilediği belirtmişlerdir. Aşağıda bir öğretmen adayını ifadesi örnek olarak verilmiştir.

> PST #33 Mülakat; Laboratuar da farklı toplumları temsil ettik ve farklı şeylere ihtiyacımız vardı ama sadece elimizde tuzlu su vardı. Bizim toplumumuz içecek suya ihtiyacımız vardı ve bizde suyu arıtarak içme suyu elde ettik. İhtiyaçlarımız bizi yönlendirdi.

Toplanan verilerin sonucunda bütün fen bilgisi öğretmen adaylarının fen laboratuarında yapılan etkinliklerle bilimsel bilginin karakteristik özellikleri arasında ilişki kurdukları belirlenmiştir. Ayrıca fen laboratuarında yapılan bu etkinliklerin bilimsel bilginin karakteristiklerinin öğretilmesi için kullanılmasının uygun olduğunu da belirtmişlerdir.

Bu kısımda bilimsel bilginin her bir karakteristiği ayrı ayrı derinlemesine analiz edilmiştir. Yansıtıcı ve sorgulamaya dayalı laboratuar öğretiminin etkisini belirlemek için öğretmen adaylarına Views of Nature of Science Questionnaire Version B (VNOS-B) ölçeği dönemin başında ve dönem sonunda uygulandı.

Bilimin doğasına yönelik karakteristiklerin ilk ve son uygulamaya göre nasıl değiştiği aşağıdaki tablolarda verilmiştir.

Tablo 1. Öğretmen adaylarının bilimsel bilginin deney temelli olmasına yönelik ilk ve son VNOS-B test görüşleri

	İlk-test (37)	Son-test (41)
	Sayı (%)	Sayı (%)
Bilimsel bilgi deney temellidir	28 (75,67 %)	35 (85,36 %)
Bilimsel bilgi deneysel kanıt gerektirir	15 (40,54 %)	14 (34,24 %)
Gözlem bilimsel bilgi için önemlidir	3 (8,10 %)	5 (12,19 %)
Kişisel fikirler sübjektiftir	28 (75,67 %)	37 (90,34 %)
Bilimsel bilgi objektiftir	8 (21,62 %)	2 (4,87 %)

Tablo 2. Öğretmen adaylarının gözlem ve çıkarım hakkındaki görüşlerinin ilk ve son VNOS-B ölçeğine göre karşılaştırılması

	İlk-test (37)	Son-test (41)
	Sayı (%)	Sayı (%)
Gözlem deneysel kanıt için gereklidir	2 (5,40 %)	5 (12,19 %)
Bilimdeki modeler için çıkarım	8 (21,62 %)	17 (41,46 %)
Gözlem ve çıkarım farklıdır	4 (10,81 %)	8 (19,51 %)
Bilimsel bilgi çıkarımsaldır	21 (56,75 %)	28 (68,29 %)
Bilimsel bilgi gözleme dayanır	15 (40,54 %)	10 (24,39 %)

Tablo 3. Öğretmen adaylarının teori ve yasa hakkındaki görüşlerinin ilk ve son VNOS-B ölçeğine göre karşılaştırılması

	İlk-test (37)	Son-test (41)
	Sayı (%)	Sayı (%)
Teoriler yaalara dönüşmez	0 (0 %)	12 (29,36 %)
Teoriler yasaları açıklarlar	4 (10,81 %)	31 (75,60 %)
Yasalar değişmezler	27 (72,97 %)	5 (12,19 %)
Teoriler değişebilir	18 (48,64 %)	38 (92,68 %)

Tablo 4. Öğretmen adaylarının bilimin sübjektif olmasına yönelik ilk ve son VNOS-B test görüşlerinin karşılaştırılması

	İlk-test (37)	Son-test (41)
	Sayı (%)	Sayı (%)
Yaratıcılık sübjektifliğe neden olur	2 (5,40 %)	9 (21,95 %)
Eğitimsel altyapı sübjektifliğe neden olur	5 (13,52 %)	16 (39 %)
Kişisel tercihler sübjektifliğe neden olur	30 (81 %)	34 (82,92 %)
Varolan teorilerin kullanılması subjektifliğe neden olur	6 (16,21 %)	21 (51,21 %)

Table 5. Öğretmen adaylarının bilimsel bilginin değişebilir olmasına yönelik ilk ve son VNOS- B test sonuçlarının karşılaştırılması

	İlk-test (37)	Son-test (41)

	Sayı (%)	Sayı (%)
Teknoloji ve yeni kanıtlar bilimsel bilgiyi değiştirebilir	7 (18,91 %)	21 (51,21 %)
Değişebilirlik bilimde gelişmeyi sağlar	3 (8,10 %)	17 (41,46 %)
Bilimsel bilgi mutlak gerçek bilgidir	11 (29,72%)	2 (4,87%)

Tablo 6. Öğretmen adaylarının yaratıcılık ve hayal gücü kakkında ilk ve son VNOS-B görüşlerinin karşılaştırılması

	İlk-test (37)	Son-test (41)
	Sayı (%)	Sayı (%)
Bilim ve sanat farklıdır	29 (78,37 %)	20 (48,78 %)
Bilim ve sanat benzerdir	20 (54 %)	36 (87,80 %)
Bilim insanları hayal gücünü kullanmazlar	5 (13,52 %)	0 (0 %)
Bilim insanları kısmen yaratıcılıklarını kullanırlar	10 (27 %)	5 (12,19 %)
Bilim insanları yaratıcılıklarını kullanırlar	20 (54 %)	38 (92,60 %)

Tablo 7. Öğretmen adaylarının sosyo kültürel etki hakkında ilk ve son VNOS-B sonuçlarının karşılaştırılması

	İlk-test (37)	Son-test (41)
	Sayı (%)	Sayı (%)
Sosyo kültürel faktörler bilimi etkiler	5 (13,52 %)	17 (41,46 %)

Öğretmen adaylarının bilimin doğasına yönelik görüşlerinin nasıl değiştiğini belirlemek için ilk ve son VNOS-B uygulaması analiz edilmiştir. Öğretmen adayların bilimin doğasına yönelik görüşleri yetersiz, kabul edilebilir ve gerçekçi olarak üç farklı kategoriye ayrılmıştır. Aşağıda sırasıyla tablolar şeklinde verilmiştir.

Tablo 8. Öğretmen adaylarının bilimsel bilginin deney temelli olması ile ilgili görüşlerindeki değişiklikler

		SON VNOS-B		
		Yetersiz	Kabul Edilebilir	Gerçekçi
İLK VNOS-B	Yetersiz	5	9	0
	Kabul Edilebilir	1	13	5
	Gerçekçi	0	0	1

Tablo 8 e göre bazı öğretmen adayları ilk uygulamada yetersiz durumdayken son uygulamada Kabul edilebilir seviyeye gelmişlerdir. Ayrıca bazıları da Kabul edilebilir seviyeden gerçekçi seviyeye yükselmiştir. Fakat tabloya göre 18 öğretmen adayının görüşlerinde herhangi bir değişiklik olmamıştır.

Tablo 9. Öğretmen adaylarının gözlem ve çıkarım hakkındaki görüşlerindeki değişiklikler

		SON VNOS-B		
		Yetersiz	Kabul Edilebilir	Gerçekçi
İLK VNOS-B	Yetersiz	2	22	3
	Kabul Edilebilir	1	3	3
	Gerçekçi	0	0	0

Tablo 9 a göre birçok öğretmen adayı dönemin başında yetersiz seviyedeyken dönemin sonunda kabul edilebilir ve gerçekçi seviyeye yükselmişlerdir. Ayrıca kabul edilebilir seviyesinden gerçekçi seviyesine yükselen öğretmen adayları da olmuştur.

Tablo 10. Öğretmen adaylarının teori ve yasa hakkındaki görüşlerindeki değişiklikler

		SON VNOS-B		
		Yetersiz	Kabul Edilebilir	Gerçekçi
İLK VNOS-B	Yetersiz	1	22	10
	Kabul Edilebilir	0	1	0
	Gerçekçi	0	0	0

Tablo 10 a göre birçok öğretmen adayı dönemin başında yetersiz seviyedeyken dönemin sonunda kabul edilebilir ve gerçekçi seviyeye yükselmişlerdir.

Tablo 11. Öğretmen adaylarının bilimsel bilginin sübjektif olması hakkındaki görüşlerindeki değişiklikler

		SON VNOS-B		
		Yetersiz	Kabul Edilebilir	Gerçekçi
İLK VNOS-B	Yetersiz	1	13	8
	Kabul Edilebilir	0	5	7
	Gerçekçi	0	0	0

Tablo 11 a göre birçok öğretmen adayı uygulamanın başında yetersiz seviyedeyken uygulamanın sonunda kabul edilebilir ve gerçekçi seviyeye yükselmişlerdir.

Tablo 12. Öğretmen adaylarının bilimsel bilginin değişebilir olması hakkındaki görüşlerindeki değişiklikler

		SON VNOS-B		
		Yetersiz	Kabul Edilebilir	Gerçekçi
İLK VNOS-B	Yetersiz	3	22	1
	Kabul Edilebilir	0	5	3
	Gerçekçi	0	0	0

Tablo 12 a göre birçok öğretmen adayı uygulamanın başında yetersiz seviyedeyken uygulamanın sonunda kabul edilebilir seviyeye yükselmişlerdir.

Tablo 13. Öğretmen adaylarının bilimsel bilginin gelişmesinde yaratıcılığın ve hayal gücünün önemi hakkındaki görüşlerindeki değişiklikler

		SON VNOS-B		
		Yetersiz	Kabul Edilebilir	Gerçekçi
İLK VNOS-B	Yetersiz	0	3	7
	Kabul Edilebilir	0	4	15
	Gerçekçi	0	0	5

Tablo 13 e göre birçok öğretmen adayı dönemin başında kabul edilebilir seviyedeyken dönemin sonunda gerçekçi seviyeye yükselmişlerdir.

Tablo 14. Öğretmen adaylarının bilimsel bilginin gelişmesinde toplumun ve kültürün önemi hakkındaki görüşlerindeki değişiklikler

		SON VNOS-B		
		Yetersiz	Kabul Edilebilir	Gerçekçi
İLK VNOS-B	Yetersiz	18	7	6
	Kabul Edilebilir	0	1	2
	Gerçekçi	0	0	0

Tablo 14 e göre bazı öğretmen adayı uygulamanın başında yetersiz seviyedeyken uygulamanın sonunda gerçekçi seviyeye yükselmişlerdir.

Sonuç olarak genellikle fen bilgisi öğretmen adayları uygulamanın sonunda bilimin doğasına yönelik görüşlerinde bir gelişme olmuştur.

Bir diğer alt araştırma sorusunda öğretmen adaylarının bilimsel bilginin karakteristik özellikleri arasında nasıl bir ilişki kurdukları araştırılmıştır. Verilerin analizi sonucunda öğretmen adaylarının toplam 180 bağlantı kurdukları ortaya çıkmıştır, bu bağlantıların sadece 7 tanesi dönemin başında toplanan verilerden elde edilmiştir, diğerleri uygulamanın sonunda toplanan verilerde görülmüştür. Aşağıdaki tabloda öğretmen adalarının bilimsel bilgini karakteristik özellikleri arasındaki bağlantılar verilmiştir.

Tablo 15. Bilimsel bilginin karakteristikleri arasındaki bağlantılar

	1	2	3	4	5	6	7
1. Deney temelli olma	-----	-----	-----	-----	-----	-----	-----
2. Gözlem ve çıkarım	15	-----	-----	-----	-----	-----	-----
3. Teori ve yasa	0	2	-----	-----	-----	-----	-----
4. Sübjektiflik	0	25	0	-----	-----	-----	-----
5. Değişebilirlik	3	4	0	7	-----	-----	-----
6. Yaratıcılık ve hayal gücü	35	28	0	30	2	-----	-----
7. Toplumsal ve kültürel etki	5	3	0	15	3	3	-----

Fen laboratuarı uygulamasından önce öğretmen adaylarına VNOS-B ölçeği uygulanmış ve bazı bağlantılar ortaya çıkarılmıştır. Örneğin aşağıdaki alıntılarda öğretmen adayları sübjektiflikle yaratıcılık ve hayal gücü arasında bağlantı kurmuşlardır.

> PST #10 Mülakat; Bilim insanlarının var olan bilgileri onların hayal güçlerini ve yaratıcılılarını etkileyebilir.

> PST #26 Mülakat; Bence bireysel farklılıklar bilimi etkiler. Aynı fosil için farklı canlılar çizdik, çünkü herkes farklı hayal güçlerine sahip. Bilim insanlarının dini inançları ve kültürleri onların hayal güçlerini etkileyebilir.

Fen laboratuar dersi sonunda öğretmen adayları birçok bağlantı kurmuşlardır. Örneğin bilimsel bilgini deney temelli olması ve gözlem ve çıkarım arasındaki bağlantılardan bazıları aşağıda verilmiştir.

PST #11 Mülakat; Bence deney bilimsel bilginin öğrenilmesinde çok önemlidir. Deney süresince, öğrenciler bütün işlemleri yapabilir ve gözlemleyebilirler.

PST #28 Mülakat; Deney yaparak öğrenme daha etkili olur, çünkü öğrenciler gözlemleyebilir ve yapabilirler. Bundan dolayı öğrenciler bilim insanları gibi bilimsel bilgiyi keşfedebilirler.

PST #8 Mülakat; Deney yapma bilimde önemli bir role sahiptir. Gözlem ve deney bilim için gereklidir.

PST #4 Mülakat; Bence gözlem sadece bilimsel araştırmalar için değil aynı zamanda günlük yaşantımız içinde çok önemlidir. Gözlem yaparken çevremizi ve onun ihtiyaçlarını anlayabiliriz. Örneğin, laboratuar da kara kutuyu gözlemledik, sonrada onun içi hakkında çıkarımlarda bulunduk. Eğer kutuyu gözlemlemeseydik, kutunun içi hakkında da çıkarımda bulunamazdık.

PST #41 Mülakat; Fotosentez ve çimlenme deneylerinde bütün süreci gözlemledik, bazen de yaptık, böylece öğrendik.

PST #45 Mülakat; Gözlemleyebildiğimiz için deney yaparak daha kolay anlayabiliriz. Laboratuar da fotosentez deneyini yaptık ve yapraklarda nişastayı gözlemledik, sonuca ulaştık.

Öğretmen adaylarının laboratuar dersinden sonra belirttikleri gözlem ve çıkarım ile teori ve yasa asasındaki bağlantıya örnek olarak aşağıda bir alıntı verilmiştir.

PST #25 Mülakat; Bu etkinlik bana teori ve yasa arasındaki ilişkiyi hatırlattı, bir yasa için teori olarak kabul edilen birkaç tane açıklama olabilir.

Öğretmen adaylarının belirttiği bilimsel bilginin sübjektif olduğu ve gözlem ve çıkarımla ilgili bağlantılar aşağıda verilmiştir.

PST #12 Mülakat; Laboratuar da aynı şeyleri gözlemledik fakat bizim çıkarımlarımız farklıydı. Bu bizim var olan bilgilerimizle yada farklı görüşlerimizle ilgiliydi.

PST #18 Mülakat; Her grup farklı yapılar geliştirdi. Bizim var olan bilgilerimiz farklıydı bundan dolayı çıkarımlarımızda farklı oldu.

PST #29 Mülakat; Laboratuar da kutuyu gözlemledik sonra her grup farklı yapılar dizayn etti. Bence bu sübjektiflikle ilgili, bizim çıkarımlarımız farklıydı. Bu etkinlikten sonra bilimsel bilginin güvenilirliği konusunda şüpheye düştüm, bütün konular için değil ama bazıları için.

PST #3 Mülakat; Gözlem yaparken var olan bilgilerimizden etkilendik, ön bilgilerimize göre gözlem yaptık. Kendi amaçlarımıza göre gözlemlerimizi yaptık, gözlem yapacağımız şeyleri seçtik.

Öğretmen adayları yaratıcılık ve hayal gücünün kullanılması ve gözlem ve çıkarım arasında bağlantı kurmuşlardır. Aşağıda bununla ilgili alıntılar verilmiştir.

PST #14 Mülakat; Bilim insanlarının aynı konu hakkında farklı çıkarımları olabileceğini anladım. Ayrıca aynı sonuca ulaşmak için farklı yolların olduğunu anladım.

PST #9 Mülakat; Bilim insanları bilimsel bilgi için bir çok teori ortaya koyuyorlar, sonra teorilerini gözlemliyorlar. Fakat onların gözlemleri ve çalışmaları önceki teorilerinden ve inançlarından etkileniyor. Bundan dolayı bilim insanları farklı sonuçlara ulaşıyorlar, bundan dolayı farklı çıkarımlara sahip olabiliyorlar.

PST #26 Mülakat; Çıkarımlar gözlemlerin yorumlarıdır ve ön bilgilerimize ve deneyimlerimize bağlıdır.

PST #9 Mülakat; Bence kutu etkinliği yaratıcılıkla ilşkili olabilir, çünkü insanlar farklı yeteneklere sahip olabilirler. Geçmişte atom hakkında farklı bilim insanları farklı atom modelleri ortaya atmışlar.

Öğretmen adayları değişebilirlik ve gözlem ve çıkarım arasında bağlantı kurmuşlardır. Örnek olarak aşağıdaki alıntı verilmiştir.

PST #30 Mülakat; Her grup farklı sistemler dizayn etti, hepside doğruydu. Bence bu bilimsel bilginin değişebilirliği ile ilgili.

Öğretmen adayları dönemim sonunda toplumun ve kültürün etkisi ve gözlem ve çıkarım arasında bağlantı kurmuşlardır. Örnek olarak aşağıdaki alıntı verilmiştir.

PST #1 Mülakat; Farklı çıkarımlar insanların farklı önbilgilerinden ve sosyal kültürel yapılarından kaynaklanıyor.

Öğretmen adayları dönemim sonunda toplumun ve kültürün etkisi ve bilimsel bilginin sübjektif olması arasında bağlantı kurmuşlardır. Örnek olarak aşağıdakı alıntı verilmiştir.

PST #24 Mülakat; Bilim insanları var olan bilgilerini kullanırlar ve sosyal kültürel yapıdan etkilenirler.

Öğretmen adayları fen laboratuarı dersinin sonunda yaratıcılık ve hayal gücünün etkisi ve bilimsel bilginin değişebilir olması arasında bağlantı kurmuşlardır. Örnek olarak aşağıdaki alıntı verilmiştir.

PST #31 Mülakat; Bence bu etkinlik yaratıcılıkla ilgili olabilir, benim anladığım bilimsel bilgi kesin değildir.

Öğretmen adayları fen laboratuarı dersinin sonunda toplumun ve kültürün etkisi ve bilimsel bilginin değişebilir olması arasında bağlantı kurmuşlardır. Örnek olarak aşağıdaki alıntı verilmiştir.

> PST #38 Mülakat; Bilimsel bilgi değişebilir, çünkü birçok insan farklı metotlarla sürekli araştırma yapıyor, ve bilim insanları yeni şeyler bulup bilimi geliştirebilirler. Hayal gücü, din, çevre ve kültür bilimi etkiler.

Bu araştırmada ikinci olarak fen bilgisi öğretmen adaylarının bilimin doğasına yönelik algılarının gelişmesinde nelerin etkili olduğu ve öğretmen adaylarının algıları ve bakış açıları incelenmiştir. Aşağıda öğretmen adaylarından yapılan alıntılar verilmiştir.

> PST #13 Mülakat; Bu dersten hoşlandım, laboratuar dan sonra bilim hakkında birçok yeni şey öğrendim. Bu dersten önce bazı laboratuar dersleri almıştım, ama bu ders çok farklıydı.

> PST #14 Mülakat; Her hafta bu derste bilim hakkında farklı şeyler öğrendim ve şaşırdım, bilim hakkındaki eski görüşlerim değişti.

> PST #20: Bu dersten önce bilimin doğası hakkında bilgim yoktu. Bilimin özellikleri başlangıçtan beri vardı fakat bize bu konuda bir şey öğretilmedi. Bu laboratuar da bilim hakkında birçok şey öğrendim. Bu dersten hoşlandım.

> PST #33 Mülakat; Bu dönemden önce bilimin doğası hakkında hiçbir şey bilmiyordum, düşüncelerim değişti. Bilimsel bilginin şimdi kesin olmadığını biliyorum ve onun yaratıcılıktan etkilendiğini. Her hafta farklı şeyler öğrendim ve heyecanlandım.

> PST #24 Mülakat; Daha önce bazı laboratuar dersleri almıştım, bu ders diğerlerinden farklıydı çünkü etkinlikleri biz yaptık ve bilimin doğasını etkili bir şekilde öğrendik. Bilim hakkındaki düşüncelerim değişti, başka bir ders için ders planları hazırladım

ve bilimin doğasını öğretmek için bazı etkinlikleri kullandım. Laboratuar da etkinliklerden sonra bilimin doğası hakkında sunumlar vardı bence onlar bizim için çok faydalı oldu.

PST #27: Her hafta bilimin doğasıyla ilgili bir özelliğine odaklandık. Teori ve yasa arasındaki ilişkiyi anladım, bilim insanlarının objektif olmadıklarını, bilimsel bilginin teori temelli olduğunu ve değişebilir olduğunu. Bu dersten önce bilim insanlarının % 100 doğru olduklarını, bilimsel bilginin kesin olduğunu ve değişmeyeceğini düşünüyordum.

PST #3: Bu laboratuar dersini sevdim. Bence bilimin doğası laboratuar da daha iyi öğretilebilir. Ben bilimin doğasını öğretmek için laboratuarı tercih ederim. Çünkü öğrenciler yaparak ve görerek öğrenebilirler. Mesela, ben bilimin doğasını bu derste öğrendim ve bu bilgilerimi farklı derslerde kullandım. Daha öncede laboratuar dersleri almıştım ama biz sadece gözlemliyorduk sonrada hiçbir şey yapmadan çıkıp gidiyorduk, bundan dolayı hiçbir şey öğrenmedik. Bu dersten önce bilimin doğası hakkında hiçbir şey bilmiyordum. Bence öğrenciler ilk olarak bilimin doğasını öğrenmeliler sonrada diğer fen konularını. Bilimle toplumu birbirinden ayırmışız, geçmişte bilimi sadece bilim adamlarının yapabileceğini öğrenmiştik. Fakat bugün bilim bütün insanların günlük yaşantısını etkiliyor bundan dolayı öğrenciler bilimin doğasını öğrenmeliler. Çünkü bilimin doğasını öğrenmek bilim okuryazarlığı ile direk ilişkili. Bu dersten sonra bilim hakkındaki düşüncelerim tamamıyla değişti.

PST #34: Bilimin doğasını bu dönem anladım. Bence bilimin doğası karmaşık bir konu ve benim bilimin doğası hakkındaki düşüncelerim değişti. Bazen sadece dinlemek veya okumak anlamak için yeterli olmuyor, bundan dolayı bilimin doğasını öğretmek için laboratuar etkinliklerini tercih ederim. Bilimin doğası hakkındaki önceki okumalarım bu laboratuar dersinde anlamlı hale geldi. Maalesef bu zamana kadar çok iyi okullarda okumama rağmen bilimin doğası halında birçok yanlış kavramlarım vardı. Şimdi hepsi değişti ve bu beni mutlu ediyor. Laboratuar da tartışma ortamları vardı ve ben bunlardan çok şey öğrendim. Her hafta bilimin doğası ve bilimsel süreç becerileri hakkındaki düşüncelerimizi yazdık. Bence bu yazılar kendi anlayışımızda bize yardım etti. Bu ders benim ve birçok arkadaşım için aldığımız en iyi laboratuar dersi oldu. İlerde bende öğretmen olacağım ve bu etkinlikleri kullanacağım.

Verilerin analizi sonucunda öğretmen adaylarının bilimin doğasına bakışlarını geliştiren üç temel faktör belirlenmiştir. Bunlar laboratuar dersi boyunca yapılan sunumlar ve tartışmalar, bilimsel süreç becerilerinin kullanılması ve sorgulayıcı metotla etkinliklerin yapılması olarak ortaya konulmuştur.

Fen laboratuarında yapılan tartışmalar ve sunumların önemli olduğu 10 öğretmen adayı tarafından ifade edilmiştir. Aşağıda bazı öğrencilerden alıntılar verilmiştir.

PST #20: Etkinliklerden sonra hocamız sunum yaptı ve bizde tartıştık, bundan dolayı bilimin doğasını kolayca anladık.

Part #34: Bu dönemden önce bazı kavram yanılgılarım vardı mesela, teorilerin yasaya dönüşeceği ve yasaların değişemeyeceği gibi. Etkinliğin sonunda sunum vardı ve kavramlar hakkında tartıştık bunlardan dolayı kavram yanılgılarımızı giderdik.

PST #4: Etkinlikleri yaparken grup arkadaşlarımızla tartıştık ve sonunda bilimsel bilgilere ulaştık. Buna ek olarak etkinliklerden sonra sunumlar vardı, bilimin doğasına yönelik anlayışımız gelişti ve bu etkinliklerle bilimin doğasını öğrendik.

Bilimsel süreç becerilerinin kullanılması bütün öğretmen adayları tarafından kendi gelişimlerinin bir etkeni olarak görüşmüştür, aşağıda bazı öğretmen adaylarının ifadeleri verilmiştir.

PST #2: Bence bilimin doğası bilimsel süreç becerileri ve bilimsel bilgi arasında bir ilişki vardır. Deneyleri yaparken biz bilimsel süreç becerilerini kullandık, buda bizim daha sistematik olmamıza yardımcı oldu, bilimde farklı metotlarda olabilir. Sonuca farklı metotlarla ulaşabiliriz. Bilimsel süreç becerilerini kullanarak laboratuar etkinliklerini yaptık.

PST #27: Bilimin doğası, bilimsel süreç becerileri ve bilimsel bilginin arasında çok sıkı bir ilişki vardır. Ben bilimsel bilgiyi ulaşmak istediğimiz bir durağa benzetiyorum, bu yolda bilimsel süreç becerileri de kullandığımız araçlar ve yolun kendini de bilimin doğasına benzetiyorum.

PST #6: Bilimin doğasını ve bilimsel süreç becerilerini birbirinden ayıramayız. Çünkü etkinlikleri yapmak için laboratuar da birçok süreç becerisini kullandık, sonunda kendimizin bilimsel bilgisini oluşturduk. Bilimin gelişmesi için bunları yapmalıyız ve sonuçları diğer insanlarla paylaşmalıyız.

Son olarak öğretmen adaylarının tümü sorgulayıcı yöntemle etkinlik yapmanın bilimin doğasına yönelik anlamalarını geliştirdiğini belirtmişlerdir. Aşağıda bununla ilgili öğretmen adaylarının ifadelerine yer verilmiştir.

PST #31: Bence laboratuar sadece bilimin doğası için değil diğer fen konuları içinde çok uygun bir öğrenme ortamı. Çünkü biz laboratuar da yapıyoruz bundan dolayı geleneksel hoca anlatımından daha iyi öğreniyoruz.

PST #37: Ben bu dersi sevdim, dersten önce laboratuar formunu okudum ve etkinlikleri kendimiz yaptık, bundan dolayı bilimin doğasını kolaylıkla anladık.

PST #40: Bence öğrenciler sınıfta direk anlatımla bilimin doğasını anlayamazlar. Laboratuardaki her şeyi hatırlıyorum, çünkü ilk olarak ilkeme düşüyorduk sonra etkinliği yapıyorduk sonrada anlıyorduk. Ayrıca, bu derse kadar hiç deney düzeneği kurmamıştım, bu derste deneyleri biz tasarladık.

Fen bilgisi öğretmeni adaylarının bu laboratuar dersinin onların gelecekteki fen öğretimleriyle ilişkisine dair görüşleri incelenmiştir. Çalışmanın başında araştırmacının böyle bir amacı olmamasına rağmen verilerin analizi sonunda öğretmen adaylarının fen öğretimine yönelik tutumlarının pozitif şekilde geliştiği belirlenmiştir. Aşağıda öğretmen adaylarından alınan alıntılara yer verilmiştir.

> Part #12: Bilimin doğasının sınıfta anlatımla öğretilebileceğini düşünmüyorum. Özellikle ilköğretim okullarında öğrenciler laboratuar dersi olmadan bilimin doğasını anlayamazlar. Bence laboratuar fen dersleri için önemlidir. Ben bilimin doğasını öğretmek için laboratuarı tercih ederim. Öğrenciler deney yapmalılar ve direk gözlem yapmalılar. Bilimin doğası hakkındaki görüşlerim bu dersten sonra değişti, eğer bu dersi almamış olsaydım buradan mezun olup fen bilgisi öğretmeni olacaktım ve öğrencilerime yanlış şeyleri öğretecektim.

> PST #17: Fen bilgisi öğretmeni olduğum zaman bilimin doğasını öğretmek için laboratuarı kullanacağım. Çünkü ilköğretim öğrencileri sözlü anlatımla bilimin doğasını anlayamazlar. Öğrencilerin bilimin doğası hakkında etkinliklere ihtiyaçları var. Bu derste biz etkinlikleri yaptık ve daha iyi öğrendik. Ayrıca biz öğretmen olacağız ve ilerde bilimin doğasını böyle öğreteceğiz.

> PST #19: Bu laboratuar diğer laboratuar derslerinden farklı. Bence sadece bilimin doğası değil diğer fen dersleri de laboratuarda öğretilmeli. Lisedeyken anlatılan fen derslerini sadece ezberliyordum sonrada unutuyordum. Laboratuar da daha iyi öğrenirim çünkü gözlemleyebilirim ve deneyleri kendim yapabilirim. Fen bilgisi öğretmeni olduğum zaman bu derste öğrendiğim bazı etkinlikleri bende kullanacağım.

> PST #25: Bu laboratuar dersi diğer laboratuar derslerinden farklıydı. Bence bilimin doğasında bir çok aspect için laboratuar ortamı faydalıdır çünkü öğrenciler yaparak daha iyi öğrenirler. Fakat bazıları da fen dersinde sınıf ortamında öğretilebilir. Bence laboratuar dersleri eğlenceli olmalı, öğrenciler dersten hoşlanmalılar. Gelecekte kendi öğrencilerime bilimin doğasını öğretmek için benzer etkinlikleri kullanacağım.

> PST #29: Bilimin doğasını öğretmek için laboratuar ortamını tercih ederim. Bence eğer öğrenciler bir şeyler yaparlarsa daha iyi öğrenirler. Fen dersleri öğrenci merkezli olmalıdır, öğrenciler gözlem yapmalılar böylece fenden hoşlanırlar yoksa fen dersleri öğrenciler için sıkıcı oluyor. Ayrıca etkinlikleri yaparken öğrenciler kendi yeteneklerini kullanabilir ve geliştirebilirler.

> PST #7: Bence fende öğrencinin katılımı çok önemli, çünkü pratik yaptıktan sonra bilimsel bilgi öğrenciler için daha kalıcı oluyor. Bence fen dersleri laboratuarda araştırmaya dayalı yöntemlerle öğretilmeli. Öğrenciler deney yapmalılar, eğer böyle yaparlarsa daha iyi öğrenebilirler. Doğrudan anlatım öğrenme için yeterli değil, çünkü öğrenciler anlatımdan sonra sadece ezberliyorlar.

> PST #8: Fen eğitimi için sınıf içinin uygun olduğunu düşünmüyorum, ben laboratuarını tercih ederim. Çünkü sınıfta sadece hocayı dinleriz, not alırız, bilgileri ezberleriz sınavdan sonrada hepsini unuturuz. Özellikle bilimin doğası laboratuarda öğretilmeli çünkü laboratuarda öğrenciler deney yapar kendi verilerini oluşturur bundan dolayı daha iyi öğrenirler.

Bu alıntılarda öğretmen adayları ilerde fen öğretmeni olduklarında bilimin doğasını öğretmek için laboratuarda sorgulayıcı araştırma yöntemini kullanacaklarını belirtmişlerdir. Öğretmen adayı geçmişte aldıkları fen dersleriyle bu laboratuar dersini karşılaştırıp bu dersi tercih etmişlerdir.

Sonuç ve Tartışma

İlk araştırma sorusunun birinci alt sorusuna göre fen bilgisi öğretmen adayları fen laboratuarında yapılan etkinliklerle bilimsel bilginin karakteristik özellikleri arasında bir ilişki kurmuşlardır. Özellikle bilimin doğasının bu etkinliklerle öğretilebileceği noktasında fikir belirtmişlerdir.

İlk araştırma sorusunun ikinci alt sorusunda öğretmen adaylarının bilimin doğasına yönelik görüşlerinde nasıl bir gelişme olduğu araştırılmıştır. Sonuç olarak hemen hemen bütün öğretmen adaylarının birçok özellikte gelişme gösterdiği belirlenmiştir.

Üçüncü alt soruda öğretmen adaylarının bilimsel bilgini karakteristik özelliklerini birbirleriyle nasıl ilişkilendirdikleri araştırılmıştır. Dönemin başında araştırmacının böyle bir amacı olmamasına rağmen dönem sonunda veri analizinde öğretmen adaylarının bu bağlantıları yaptıkları tespit edilmiştir.

İkinci araştırma sorusunda öğretmen adaylarının bu laboratuar sersinden sonra deneyimlerine bağlı olarak bilimin doğasının öğretimi hakkında görüşlerinin nasıl değiştiği incelenmiştir. Sonuç olarak öğretmen adaylarının bilimin doğasının öğretimine yönelik pozitif tutum geliştirdikleri belirlenmiştir.

Sonuç olarak daha önce bu alanda yapılan çalışmalar genellikle fen öğretimi (method) derslerinde uygulanmıştır. Bu çalışma bunu fen laboratuarında yapmıştır ve etkili olduğu görülmüştür.

Appendix J

CURRICULUM VITAE

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2. Quantitative Data Analysis in Education (ESME 506)
3. Educational Inquiry (ESME 509)
4. Test Construction in Science and Mathematic Education (SSME 540)
5. Issues in Environmental Education (ESME 563)
6. Independent study in Elementary Math. and Science Education (ESME 572)
7. Instructional Design (EDS 541)
8. Cognitive Development in Scien. and Math. Education (SSME 650)
9. Analysıs of Research in Elementary Math.& Science Education (ESME 560)
10. Advance Data Analysis in Educational Research (SSME 703)
11. Advanced Educational Research (ELE 603)
12. Contemporary Philosophies of Education (EDS 578)
13. Curriculum in Elementary Mathematics and Science Educatıon (ESME 547)
14. Seminar in Elementary Science and Mathematics Education (ESME 550)

GPA: 3.89/4.0

1998-2002 Abant İzzet Baysal University
Bolu, TURKEY
B.S. , Elementary Science Education

1995-1998 Erzurum Mecidiye High School
Erzurum, TURKEY

WORKING EXPERIENCE

April 2004- …. Research Assistant
Middle East Technical University
Faculty of Education
Department of Elementary Education

Courses offered as Instructor

1. Lab. Applications in Science I
2. Lab. Applications in Science II

Courses offered as Research Assistant

1. Probability and Statistics
2. School Experience II
3. Practice Teaching in Elementary Education
4. Educational Inquiry

Other tasks at the department

Advisor of thirth grade students in elementary mathematic education
Condinator of the elementary science labaratory

2002-2004 Elementary Science Teacher
Ali Ericek Elementary School
Göynük, Bolu, TURKEY

FOREIGN LANGUAGES

English: Advance (TOEFL- 213 CBT, 2005)

COMPUTER SKILLS

Windows, MS Word, MS Excel, MS PowerPoint, Internet Explorer, Paint Shop, SPSS

PAPERS PRESENTED AT INTERNATIONAL CONFERENCES

1. **Ozgelen, S.,** & Yilmaz-Tuzun, O. (2007). Preservice Science Teachers' Perceptions about Science Process Skills and Their Practices. Paper presented; American Educational Research Association Chicago, USA. April 09-13, 2007.

2. Yilmaz-Tuzun, O., & **Ozgelen, S**. (2007). Preservice Science Teachers' Reflections about Application of Science Process Skills: A case study. Paper presented; National Association for Research in Science Teaching New Orleans, USA. April 14-19, 2007.

3. Hacieminoğlu, E., **Ozgelen S.,** Tuzun Yılmaz, O. (2007). Investigating Pre-service Teachers' Learning Approach and Epistemological Beliefs in Inquiry Learning Environment. *European Science Education Research Association, page:220, August 21-25, 2007, Malmö, Sweden.*

4. **Ozgelen S.,** Hacieminoğlu, E., Tuzun Yılmaz, O. (2007). Investigation the Effect of Inquiry Method for Student's Science Process Skills through Word Association Test. *European Science Education Research Association, page:221, August 21-25, 2007, Malmö, Sweden.*

5. **<u>Ozgelen S.,</u>** Hacieminoğlu, E., Tuzun Yılmaz, O. (2008). Investigation of pre-service teachers' reasoning abilities and learning approaches in inquiry based learning environment. *National Association for Research in Science Teaching (NARST)* Baltimore, MD, USA

6. Hacieminoglu, E., **<u>Ozgelen, S.,</u>** & Yilmaz-Tuzun, O. (2008). Pre-service teachers' perceptions and motivations toward a science laboratory course. XIII. IOSTE, The Use of Science and Technology Education for Peace and Sustainable Development, 491-501, Kuşadası, Turkey.
7. **<u>Ozgelen, S.,</u>** Hacıeminoglu, E., & Yilmaz-Tuzun, O. (2008). Effect of inquiry instruction and gender on students' science process skills, epistemological beliefs and learning approaches in Turkish context. XIII. IOSTE, The Use of Science and Technology Education for Peace and Sustainable Development, 1266-1273, Kuşadası, Turkey.

8. **<u>Özgelen, S.,</u>** Hanuscin, D., & Yılmaz-Tüzün, Ö. (2009). The impact of inquiry-based laboratory instruction and explicit-reflective teaching on preservice science teachers' nature of science views. European Science Education Research Association (ESERA), İstanbul, Turkey.

<u>PAPERS PRESENTED AT NATIONAL CONFERENCES</u>

1. **<u>Ozgelen, S.,</u>** & Yilmaz-Tuzun, O. (2006). The quality of preservice science teachers' practices for science process skills. VII. Science and Mathematics Conference, Gazi University, Ankara, TURKEY. September 07-09, 2006.

2. Hacieminoğlu, E., **Ozgelen S.,** Tuzun Yılmaz, O. (2007). Investigation of preservice science teachers' perceptions towards science laboratory practice course. I. National Elementary Conference, page. 74, Ankara, TURKEY. November 15-17, 2007.

3. **Ozgelen S.,** Hacieminoğlu, E., Tuzun Yılmaz, O. (2007). Effect of inquiry oriented lesson on development of pre-service teachers' science process skills. I. National Elementary Conference, page. 84, Ankara, TURKEY. November 15-17, 2007.

PROJECTS

1. Scientific Research Project (BAP-08-11-DPT-2002K120510). "Determinig elementary sixth and seventh grade students' science process skills." (As a Researcher)

CERTIFICATE

I received the Project Cycle Management in 2005 from a private organization in Ankara, and I am certified that I could review EU projects. This certification program lasted about four weeks. In 2006 January, I applied an EU project with my colleagues about teachers' teaching methods and their assessment strategies.

MEMBERSHIP OF PROFESSIONAL BODIES

NARST (National Association of Research in Science Teaching)—2007-2008