THE EFFECT OF USING METACOGNITIVE STRATEGIES EMBEDDED IN EXPLICIT-REFLECTIVE NATURE OF SCIENCE INSTRUCTION ON THE DEVELOPMENT OF PRE-SERVICE SCIENCE TEACHERS' UNDERSTANDINGS OF NATURE OF SCIENCE

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF SOCIAL SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

AYTUĞBA BARAZ

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
THE DEPARTMENT OF ELEMENTARY SCIENCE EDUCATION

SEPTEMBER 2012

Approval of the Graduate School of Social Sciences

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ABSTRACT

THE EFFECT OF USING METACOGNITIVE STRATEGIES EMBEDDED IN EXPLICIT-REFLECTIVE NATURE OF SCIENCE INSTRUCTION ON THE DEVELOPMENT OF PRE-SERVICE SCIENCE TEACHERS' UNDERSTANDINGS OF NATURE OF SCIENCE

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September 20012, 184 pages

The current study aimed to investigate the effect of using metacognitive strategies embedded in explicit–reflective NOS instruction to improve NOS understanding of pre-service science teachers. Metacognitive Awareness Inventory (MAI) (Schraw & Dennison, 1994) and Views of Nature of Science Questionnaire (VNOS-C) (Lederman et al., 2001) were used both at the beginning and at the end of the study as a pre-test–post-test, comparison group, quasi-experimental design. A total of 33 pre-service science teachers (PSTs), 24 were female and 9 were male agreed to join the study voluntarily. These students were selected for this study while they were enrolling at their 5th semester in which they attended Methods of Teaching Science I course offered by the faculty of education at Middle East Technical University. Participants were divided into two groups namely comparison and intervention group. Explicit reflective NOS instruction was used in both groups, but metacognitive strategies additionally used in intervention group. Data analysis demonstrated that explicit reflective NOS instruction enhanced the development of understanding of NOS in both groups. Results also showed that metacognitive strategies improved the metacognitive awareness of intervention group participants. Although four of these metacognitive strategies and explicit reflective NOS instruction in present study provided a substantial increase in NOS understandings of PSTs in intervention group, chi-square analysis showed statistically no significant difference between comparison and intervention group participants' post-test results.

Keywords: Nature of Science, Explicit Reflective NOS Instruction, Metacognition, Metacognitive Strategies

ÖZ

DOĞRUDAN VE YANSITICI ZİHİN ÜSTÜ DÜŞÜNME BECERİLERİ KULLANILARAK OLUŞTURULAN BİLİMİN DOĞASI ÖĞRETİMİNİN FEN VE TEKNOLOJİ ÖĞRETMEN ADAYLARININ BİLİMİN DOĞASI ANLAYIŞLARINA OLAN ETKİSİ

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Eylül 2012, 184 sayfa

Bu çalışmanın amacı doğrudan yansıtıcı bilimin doğası öğretimi içine oturtulmuş zihin üstü düşünme becerileri kullanmanın fen ve teknoloji öğretmen adaylarının bilimin doğası anlayışlarını geliştirmedeki etkisini incelemektir. Veriler Metacognitive Awareness Inventory (MAI) (Schraw & Dennison, 1994) and Views of Nature of Science Questionnaire (VNOS-C) (Lederman et al., 2001) ölçeklerinin ön test ve son test olarak kullanılması sonucu toplanmıştır. 24 kadın ve 9 erkek olmak üzere 33 öğretmen adayı (PSTs) çalışmaya gönüllü olarak katılmayı kabul etmişlerdir. Bu katılımcılar ODTÜ Eğitim Fakültesi tarafından verilen *Öğretim Yöntemleri I* dersine katılan 5'inci yarıyıl öğrencileri arasından seçilmişlerdir. Halihazırda iki gruba ayrılan öğrencilerden birinci gruptakiler kontrol grubu, ikinci gruptakiler deney grubu olarak nitelendirilmişlerdir. Doğrudan yansıtıcı eğitim her iki grupta da uygulanmış, buna ek olarak deney grubunda zihin üstü düşünme becerileri de kullanılmıştır. Yapılan analiz sonuçları doğrudan yansıtıcı Bilimin

Doğası eğitiminin öğretim sürecine katılanların anlayışlarında gelişmeler yaşandığını ortaya koymuştur. Ayrıca, elde edilen sonuçlar kullanılan dört farklı zihin üstü düşünme becerisinin deney grubunun zihin üstü farkındalığını artırdığını göstermiş olup, bu durum deney grubunun NOS bilgilerinde meydana gelen artışı daha da yükseltmiştir. Çalışmada kullanılan dört zihin üstü düşünme becerisi ve doğrudan yansıtıcı Bilimin Doğası Eğitimi, deney grubu öğretmen adaylarının Bilimin Doğasına yönelik anlayışlarında önemli artış sağlamasına rağmen, Ki-Kare analizi sonucu, kontrol ve deney grubu katılımcılarının son test sonuçları arasında istatiksel açıdan önemli bir fark olmadığını göstermiştir.

Anahtar Kelimeler: Bilimin Doğası, Açık ve Yansıtmacı Öğretim, Zihin Üstü Düşünme, Zihin Üstü Düşünme Becerileri

I dedicate this study to

To my beloved mother, Mahide Baraz;

brother K. Baturhan Baraz

and

in loving memory of my father, Mehmet Baraz

ACKNOWLEDGEMENTS

A special thanks to my supervisor Prof. Dr. Jale ÇAKIROĞLU for her guidance, insight, and encouragement. Completing this project has been a long and difficult process, marked by unexpected situations and changes. Her expertise, kindness, and patience have left an indelible impression upon me. I thank you very much indeed.

I also would like to thank Mesut EROL for his continuous support at all levels especially in data collection procedure of this study. My dear friends Ceyda ALTINÇAĞ, Betül YILDIRIM, Gamze TEZCAN, Ümran ALAN, Nurcan CANSIZ, Mustafa CANSIZ, Hasan ÜNKER, Şenol YILDIRIM. They were always with me on my weary times throughout this study. It is a great privilege having close friends like you. I am very thankful to you all indeed.

I also would like to express my greatest appreciation to my thesis examining committee members Prof. Dr. Ceren TEKKAYA and Assoc. Prof. Dr. Esen UZUNTİRYAKİ for their willingness to serve on the committee, the time and effort they spent, and their valuable comments, suggestions, contributions and feedbacks.

I also wish to thank my manager Dr. Güler Manisalı DARMAN. I am indebted to her for her support and patience in any time. Thank you my dearest office mate Melike ACARDAĞ and Murat DARMAN. Your presence facilitated this tiring endeavor.

I am also thankful for my dear friend Gamze ÇETİNKAYA who has always been helpful and supportive in many ways during this hard process.

Thanks also extended to all my uncles, aunts and cousins for their support in my difficult times. Having such a big and lovely family is a big chance for me.

I am most thankful for the support, love, and patience of my mother Mahide BARAZ and brother K. Baturhan BARAZ. Thank you for the courage and support you offered. It was not easy for you too. Without you, this would not have happened. I feel myself very lucky having such a family like you. I love you so much.

Finally, special thanks to my father Mehmet BARAZ, I only hope I can offer back to you a portion of the trust and big love you have offered me. You will be always with me and I will always feel your support and encouragement.

Thank you all very much indeed.

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LIST OF ABBREVIATIONS

PST : Pre-service Science Teacher

MAI : Metacognitive Awareness Inventory

VNOS-C : Views of Nature of Science Questionnaire

CHAPTER I

INTRODUCTION

The preparation of scientifically literate students is a continuing goal of science education, and an adequate understanding of nature of science (NOS) is a central component of scientific literacy (Lederman, 1992). Although “there is not a consensus about specific definitions, some aspects of NOS are shared and considered as non-controversial” (Wahbeh, 2009, p.17).

One of the earliest and commonly used definitions of NOS was that it refers to the values and assumptions inherent to the development of science knowledge (Lederman & Zeidler, 1987). NOS has many aspects which have such importance for the meaningful understanding of scientific knowledge (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). These aspects of NOS were described as; scientific knowledge is tentative, scientific knowledge is based on evidence and observation, there is no hierarchy between theory and law, laws and theories have different roles in science, scientific knowledge is theory-laden, scientific knowledge is embedded in social and cultural context, there is no universally accepted one way to do science, creatity and imagination are important to produce scientific knowledge, scientist is not objective when he or she begins to study, he or she has a background, science is a way of knowing (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; McComas, 1998).

Despite the fact that the importance of NOS has been accepted in science education community, many studies that assess elementary students’ conceptions of NOS have found that they do not possess an adequate understanding of NOS (e.g. Kang & Wallace, 2004). One explanation for students’ deficiency in understanding of conceptions of NOS is that the majority of elementary and secondary teachers seldom explicitly address this topic in their science classes. In addition, many studies consistently have shown that pre-service science teachers, as well as experienced science teachers do not possess adequate understandings of NOS (Abd-El-Khalick, Bell & Lederman., 1998). Teachers have been shown to hold a simplified view of science including a belief in one scientific method, a belief in the objective nature of science, and misunderstandings of the influence of personal, social, and cultural factors on science and scientific findings (Lederman & Abd-El-Khalick 1998). It is impossible for teachers to teach appropriate views of NOS without holding appropriate views themselves. Teachers’ conceptions of science endeavors translated into classroom practices, and thus teachers’ conceptions of NOS were significantly related to their students’ conceptions (Wellington & Nott, 1998). In addition, Akerson et al. (2000) pointed out that elementary science teachers held naïve views of a number of important aspects of NOS, and therefore minimized NOS instruction and learning experiences for students. Therefore, a major task for elementary science teacher educators is to improve elementary teachers’ understandings of NOS so they can help their own students develop appropriate ideas.

For several decades, science teacher educators have been attempting to improve elementary teachers’ NOS understandings by using different instructional methods and strategies. In order to increase the effectiveness of these strategies, they should be embedded in explicit approach (Abd-El-Khalick & Akerson, 2004; Abd-El-Khalick Lederman, 2000b; Bell, Lederman, & Abd-El-Khalick, 1998; Lederman, 1992a, 1999; Lederman et al., 2001, 2002; Hanuscin, Lee & Akerson, 2011).

Abd-El-Khalick and Lederman (2000a) identified two approaches to improve pre-service and in-service science teachers’ NOS understanding. In implicit approach, giving NOS is not direct aim but natural consequence of science education. However, in explicit approach NOS and its aspects are targetted by instructioanl sequences (Abd-El-Khalick & Lederman, 2000a). Explicit reflective approach in NOS instruction plays an important role in improving elementary teachers’ views of NOS when it is considered as a key point of learning as conceptual change (Abd-El-Khalick & Akerson, 2004). At this point; metacognition can be one of the most important factors which enhance the effectiveness of explicit reflective NOS instruction.

Teaching NOS didactically is not efficient enough for students to provide a meaningful learning and meaningful understanding of NOS (Peters, 2004). For realizing the major connections between scientific knowledge and knowledge about science, it is important for students to teach NOS in the context of scientific knowledge (Duschl, 1990). In order to understand the aim of NOS, students firstly learn to think about why they are doing the processes in science, and evaluate their thinking in terms of the way a scientist might think about the processes and outcomes (Peters, 2004). Therefore, metacognitive strategies provide students to think about their thinking, that they get meaningful knowledge by evaluating every step of learning (Baek, Park & Kim, 2009)

From these points of views, the present study aimed to examine the effectiveness of metacognitive strategies embedded in explicit-reflective NOS instruction in improving pre-service science teachers' understanding of NOS.

More specifically, the study is guided by the following research question:
What is the effect, if any, of using metacognitive strategies embedded in explicit–reflective NOS instruction on the development of pre-service science teachers' understandings of NOS?

1.1. Definitions of Important Terms

1.1.1. Nature of Science

The phrase "nature of science" is used to refer to "the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge" (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002, p. 497).

1.1.2. Explicit Reflective Instruction

The term 'explicit' is curricular in nature while the label 'reflective' has instructional implications. In "explicit reflective" instruction, explicit does not refer to didactic or explicit teaching strategies, it requires the importance of NOS understanding which is a cognitive outcome, so it should be addressed and targeted intentionally (Khishfe & Abd-El-Khalick, 2002). Explicit reflective NOS instruction is used in the present study.

1.1.3. Metacognition

"In any kind of cognitive transaction with the human or non-human environment, a variety of information processing activities may go on. Metacognition refers, among other things, to the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data on which they bear, usually in service of some concrete goal or objective." (Flavell, 1981, p.232).

1.1.4. Metacognitive Strategies

Metacognitive strategies are the techniques that increase the awareness of individual's thought processes while completing the tasks (Jansiewicz, 2008). Four metacognitive strategies are used in present study. These strategies are reflection papers, case studies, researching the development of the ideas of peers and concept maps.

1.2. Purpose of the Study

Regarding the existing literature pre-service science teachers NOS understanding and improved metacognitive awareness, this study intends to investigate the effect of using metacognitive strategies to improve the NOS understanding of pre-service science teachers.

1.3. Research Questions

In the present study, the effect of using metacognitive strategies to improve the NOS understanding of pre-service science teachers is addressing through the following research questions:

1. What is the effect, if any, of using metacognitive strategies embedded in explicit–reflective NOS instruction on the development of pre-service science teachers' understandings of NOS?
    a. What are PSTs' NOS understandings before the NOS instruction?
    b. What are PSTs' NOS understandings after the NOS instruction?
2. What is the effect, if any, of using metacognitive strategies embedded in explicit–reflective NOS instruction on the development of pre-service science teachers' metacognitive awareness?

1.4. Significance of the Study

NOS has been and continues to be a focus theme as an important learning outcome for science education (e.g. Lederman, 2007). Most of the countries are doing explicit pronouncements about NOS in their national educational reform documents (e.g., AAAS, 1990; Council of Ministers of Education Canada [CMEC] Pan-Canadian Science Project, 1997; Curriculum Council [Western Australia], 1998; Millar & Osborne, 1998; NRC, 1996). Also, Turkish national science curriculum has emphasized the importance of NOS by addressing the scientific literacy as a vision that ''all students, regardless of individual and cultural differences, should develop scientific and technological literacy'' (Ministry of National Education [MoNE], 2000, p. 9). That means Turkish national science curriculum points out the importance of understanding of the nature and development of scientific knowledge, and of the interactions between science, technology, and society (Dogan & Abd-El-Khalick, 2008). However, research studies have consistently shown that both students and teachers have naïve ideas about the structure of epistemological scientific knowledge (Abd-El-Khalick, Bell & Lederman., 1998; Abell & Smith, 1994; Kang & Wallace, 2004). It is not logical to expect holding such naïve views of teachers to teach appropriate views of NOS. Therefore, in order to help students develop appropriate views of NOS, teachers need to have informed views of scientific endeavors.

There are many studies that examine and evaluate in-service and pre-service science teachers' understandings of NOS and related factors (Abd-El-Khalick, 2001; Abd-El-Khalick & Akerson, 2004; Abd-El-Khalick & Lederman 2000a, 2000b; Lederman, 1992, 1999; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Lederman et al., 2001). Also, there have been many attempts to improve the pre-service and in-service science teachers' NOS understandings by using different strategies (e.g., Abd-El-Khalick & Lederman, 1998). In order to increase the effectiveness of these strategies, they should be embedded in explicit approach (Abd-El-Khalick & Akerson, 2004; Abd-El-Khalick & Lederman, 2000b; Bell, Lederman, & Abd-El-Khalick, 1998; Lederman, 1992a, 1999; Lederman et al., 2001, 2002; Hanuscin, Lee & Akerson, 2011). Recent studies have also shown that using explicit reflective approach improved pre-service science teachers' NOS understandings (Abd-El- Khalick & Akerson, 2004; Kucuk, 2008; Yalcinoglu & Anagun, 2012). In that point, what is needed is an examination of a deep understanding of NOS which can be provided by developed metacognitive strategies (e.g. Fountas & Pinnell, 2000). Therefore, metacognitive strategies can be used in order to increase the effectiveness of explicit reflective approach. There are few studies in the literature indicating the relationship between participants' NOS understandings and developed metacognitive strategies. While pre-service teachers' metacognition is not an issue that is often addressed in literature; the focus was generally students' metacognition on their thinking and learning processes. Therefore, the present study aims to improve the NOS understandings of pre-service science teachers by the help of metacognitive strategies.

National Science Teachers' Association (NSTA, 1982), The National Science Education Standards in the US (NRC, 1996) suggest that the most direct way to improve science education is high quality teaching. It focuses on better teacher preparation and quality to develop students' informed understanding of NOS.

Therefore, pre-service science teachers must be well grounded in content knowledge—including NOS, and capable of raising the achievement levels of their students (Abd-El-Khalick & Akerson, 2009). This aim can be best reached by enhancing metacognitive strategies that provide pre-service science teachers not only develop their conceptual understandings and integrated skills but also to internalize understandings of NOS. Therefore, four metacognitive strategies used in present study including concept mapping (Novak, 1990; Novak & Gowin, 1984), researching the development of the ideas of peers (Oldfather, 2002), writing two reflection papers about two journal articles related to NOS and response to a case study (Thomas & Barksdale-Ladd, 2000). All these strategies provide participants to think in a metacognitive manner (Hartman, 2001; McCormick, 2006; Schraw & Dennison, 1994). Pre-service science teachers do (a) planning, which helps them define what the problem is, and select an appropriate solution strategy, (b) monitoring the effectiveness of the solution strategy, and (c) regulate themselves while learning in order to identify and overcoming obstacles to solving the tasks in front of them and (d) evaluating the end results. From that end, it could be concluded that PSTs can increase their NOS understandings by empowering the effectiveness of explicit reflective NOS instruction. It was carried out by using metacognitive strategies which provide them to think in a metacognitive manner and meaningful understanding.

Abd-El-Khalick and Akerson's study (2009) gave an insight for the present study. Similar to Abd-El-Khalick and Akerson's (2009) study the present study is related to the development of NOS understandings of pre-service teachers using explicit reflective NOS instruction and metacognitive strategies. Abd-El-Khalick and Akerson (2009) aimed to develop the pre-service science teachers' understanding NOS regarding five aspects with using three metacognitive strategies which were reflection papers, concept mapping and case study. However, in present, it was aimed to develop pre-service science teachers' understanding of seven NOS aspects using reflection papers, case studies, researching the development of the ideas of peers and concept maps.

The results of the study will provide insight to science teacher educators about NOS instruction to help their pre-service teachers develop informed NOS understandings.

CHAPTER II

REVIEW OF RELATED LITERATURE

In order to frame out this study, literature reviews regarding nature of science, metacognition and metacognitive strategies are shared in following sections.

2.1. Nature of Science

One essential aspect of being a scientifically literate is to understand the fundamentals of nature of science. Nature of science (NOS) does not fit the idea that science is deterministic and absolute, because science is naturally inductive that it is not possible to get the whole before making any claims about any natural phenomenon (Horner & Rubba, 1978; Tasar, 2003). In general, NOS aims the epistemology of science, science as a way of knowing, and the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992). The nature of science can also be thought as the culture of science. However, philosophers, historians and sociologists of science are quick to disagree on exact definitions of nature of science. That disagreement can be considered as inevitable when it is thought NOS is multifaceted and complex (Abd-El-Khalick, Bell, Lederman & Schwarts, 2001). According to Suchting (1995), as our understanding of the universe and scientific knowledge increases, our views on the NOS are themselves likely to evolve. Therefore, conceptualization of NOS has changed, being reflected by philosophical, sociological and historical changes, thus 'NOS' was defined many times during the past 100 years (Abd-El-Khalick & Lederman, 2000b). These definitions from early 1900s to 2000s are exemplified in Table 2.1.

Table 2.1. The Change in NOS Definitions in Different Periods

Period	Definition of NOS
Early 1900s	Nature of science equals to understanding 'The Scientific Method' (Central Association for Science & Mathematics Teachers, 1907).
1960s	Emphasis on enquiry and science process skills (e.g. observing, hypothesizing, inferring, interpreting data, and designing experiments).
1970s	Scientific knowledge as being tentative, public, replicable, probabilistic, humanistic, historic, unique, holistic and empirical (The Center of Unified Science Education at Ohio State University, 1974).
1980s	Theory-laden nature of observation and the role of creativity and social structure of scientific organizations started to appear in definitions of NOS (NSTA, 1982).
1990s	Scientific activities are theory-laden and scientists conduct their investigations from within certain frameworks of reference (California Department of Education, 1990). NOS understanding require three basic components. The first one is *world is understandable*, but science cannot answer all questions about it yet. The second component is about scientific inquiry that it does not involve imagination and the invention of explanations. The third component is about the importance of the social and political aspects of science (Science for All Americans, 1990). NOS have historical, tentative, empirical, logical, and well-substantiated claims. Also, personal, societal and cultural beliefs are important for the development of scientific knowledge (National Science Education Standards, 1996).
2000s	There is an acceptable level of generality about NOS which is accessible to K-12 students and related to their daily lives (e.g. Elby & Hammer, 2001).

As it can be seen from the literature of NOS, it is not wrong to say scientific conceptions of NOS are also tentative and historical (Abd- El Khalick & Lederman, 2000a). Scientists have inherent, agreed upon processes and assumptions (Lederman, 1999) that help them to construct meaningful knowledge.

Lederman (1986) asserted in his earlier works that in many studies a standardized definition of a fully formed understanding of the nature of science with precise criteria for pre-college students does not exist. Also, Abd-El-Khalick, Bell, Lederman and Schwarts (2001) claimed that disagreement exists among philosophers, historians, sociologists, and science educators about NOS are irrelevant to K-12 instruction. However, there is also a shared wisdom and some generalizations in some aspects of NOS (Smith, Lederman, Bell, McComas, & Clough, 1997).

Within a particular line of research, some of the aspects of NOS that can be mentioned under this level of generality are Lederman and his colleagues' proposed seven general aspects/characteristics of NOS (Abd-El-Khalick, Bell, & Lederman, 1998). These aspects are that scientific knowledge is: "tentative (subject to change); empirically-based (based on and/or derived from observations of the natural world); theory-laden; partially based on human inference, imagination and creativity; and socially and culturally embedded" (Abd-El-Khalick & Lederman, 2000b, p. 1063). Four other aspects of NOS that have been emphasized are the distinction between observation and inferences, the relationship between theories and laws, the myth of the scientific method, and the social dimension of scientific knowledge (Akerson, Abd-El-Khalick & Lederman, 2000).

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 are used in the present study. Table 2.2 presents these definitions.

Table 2.2. 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.
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

Table 2.3. NOS Aspects and Their Definitions (cont'd)

	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 & Crawford, 2004, p.613

These NOS aspects were chosen to guide the current assessment and analysis of individuals' understandings of NOS, because they are not controversial, they are developmentally appropriate for elementary students and arguably important for all high school graduates to know (Akerson, Abd-El-Khalick & Lederman, 2000). In addition, reasoning NOS provide students to develop their intellectual independence by asking the importance of the evidence, judging if it is acceptable or not, or considering the different views (Munby & Roberts, 1998)

The nature of science education has become progressively more important in science education since the 1950s. Teaching the nature of science in combination with the history of science offers many opportunities for students to broaden their understanding of both science and history.

2.1.1. Student Understanding of NOS

Developing students' understanding of NOS is an important subject paid more attention in recent years (Kang, Scharmann & Noh, 2004). As most of the studies have shown, both teachers and students have inaccurate and inappropriate views of NOS except the instruments/methods used in the investigations (Lederman, 1992). Although adequate understanding of NOS has such an importance, the reason for students to have such a limited view should be considered.

Students' general epistemological development gives more information about their views on NOS (Kang, Scharmann & Noh, 2004). Epistemology is concerned with the nature, sources and limits of knowledge (Klein, 2005). Therefore, it can be inferred that epistemology of science is related to NOS and scientific knowledge (Kang, Scharmann & Noh, 2004). According to Piagetian development framework, an elementary student is in a concrete operational reasoning stage that he/she is absolutist and/or a naïve realist at that age (e.g. King & Kitchener, 1994). When teachers looked at child psychology in a limited view, they think as children are on concrete stage, they are not capable of using science process skills (Akerson & Donelly, 2010). Therefore, it is difficult for elementary students to have an adequate understanding of NOS.

Lederman and O'Malley (1990) suggested that students should be taught NOS in their early academic careers in order not try to change inadequate images about science in their older ages. Moreover, Bruner (1993) emphasized that elementary school is the time that students start to have formal science instruction and understand the world around them better.

On the other hand, some theorists (e.g. Montgomery, 1992; Wellman, 1990) argued that elementary students can develop epistemological thoughts that lead them to be able to understand NOS not perfectly, but explanatory. Metz (2004) argued that if the learning environment was designed well, it would have influenced students' scientific inquiry that they could use their abilities to interpret their investigations. In addition, if new concepts were taught by linking them to their existing conceptions of students, it would be more easier for students to get the new knowledge, because according to conceptual change theory, elementary students' existing knowledge is very resistant to change and influence the new one (Kang, Scharmann & Noh, 2004).

Although some research showed that up to six grade, students are capable of improving their NOS understandings, Akerson and Abd-El-Khalick's (2005) study indicated that fourth grade elementary students' NOS understandings did not improve despite emphasizing NOS through classroom activities by a teacher with an informed view of NOS.

The other important tools that influence the NOS understanding of students are school curriculums and textbooks. In general, textbooks do not require materials to be used for science explorations; whereas the kit-based programs are better that they include most of the materials for carrying out investigations about important science concepts (Akerson, Buzzelli & Donnelly, 2010). However, none of which address NOS explicitly (Akerson, Buzzelli & Donnelly, 2010). Meichtry (1992), who found no effect of BSCS (Biological Sciences Curriculum Study), claimed that the program failed to provide students to develop new knowledge and revise or replace the existing knowledge to it, because the program does not take into account students' existing knowledge about NOS.

Abd-El-Khalick and Lederman (2000a) argued that the failure of curricula and some research are due to the fact that it is believed students learn NOS automatically when they study science and engage in inquiry activities. However, learning NOS should be taken as a cognitive process and planned carefully, should not be considered as a secondary product or side effect. Therefore, they recommended teachers to give explicit attention to NOS aspect and take into consideration students' awareness about them by their reflections from various activities.

Kang, Scharmann and Noh (2004) investigated a study with 1702 Korean 6^{th}, 8^{th} and 10^{th} graders. They examined the students' views of purpose of science, definition of scientific theory, nature of models, tentativeness of scientific theory and origin of scientific theory. Students were administered to complete multiple-choice questionnaire with an accompanying open ended questions to collect the rationale for their choices. At the end of the study, the results indicated that majority of Korean students possessed an empiricist perspective about NOS and there appeared a big difference between Western countries in results. On the other hand, no significant differences were found between 6^{th}, 8^{th} and 10^{th} grade students' views about NOS.

In a different study, Khishfe (2007) studied with 18 seventh grade students to examine their NOS understandings in the inquiry- oriented instructional approach. The students taught by a teacher with appropriate knowledge about NOS for three months. The students handled three inquiry oriented activities following reflective discussions of NOS. An open ended questionnaire and semi structured interview were used to assess students before, during and at the end of the intervention. The results showed that before the intervention, the students had naïve views on the tentative, empirical, inferential, and creative aspects of NOS. During the instruction the students had intermediate views of NOS aspects. At the end of the intervention, it is concluded that the students' views of NOS had developed and reached more informed views.

The primary goal of science education should be to develop students' understanding of NOS, so research on students' conceptions of NOS is the inevitable extension of this goal (Lederman, 2007). On the other hand, even if a wide variety of assessment instruments had been used in studies, students' still do not have an adequate understanding of NOS. In that point the question arises, if young children's development levels affect their understanding of NOS aspects, could appropriate instruction of teachers be effective on it (Akerson & Donelly, 2009). Therefore, it is clear that for improving students' NOS understandings, pre-service and in-service elementary teachers should develop teaching strategies in which they emphasize NOS aspect (Akerson, Abd-El-Khalick, & Lederman, 2000; Akerson & Hanuscin, 2007; Akerson & Volrich, 2006).

2.1.2. Teachers' and Pre-service Teachers' Understanding of NOS

Scientific literacy requires knowing how science works. Therefore, most of the scientists agreed that understanding NOS is a critical objective of science teaching (American Association for the Advancement of Science, 1989). It is safe to assume that teachers cannot possibly teach what they do not understand (Shulman, 1990). It is important that teacher preparation programs should be constructed in order to prepare highly qualified teachers (Darling-Hammond & Baratz-Snowden, 2007). A highly qualified teacher should teach according to national reforms (AAAS, 1993; NRC, 1996) to develop K-12 students' knowledge of content including the nature of science. Students should have an understanding of not only science content, but also how science works that means the values and assumptions scientists make while developing scientific knowledge, or the NOS. Scientific knowledge without NOS, become a list of facts to memorize (Akerson, Morrison & McDuffie, 2006)

Teachers are one of the most important elements in schools' science programs (Vaidya, 1993; Yager, 1989). In recent decades, both pre-service and in-service science teachers' knowledge and beliefs became important (Kagan, 1992; Pajares, 1992; Pomeroy, 1999; Shulman, 1986, 1987). Teachers' understanding of NOS has a powerful influence on their teaching style (Grossman, 1989; Shulman, 1986; Wilson, Shulman & Richert, 1987). Therefore, teachers' improved view of NOS is surely important but not sufficient, because teachers, who have informed views of NOS, do not necessarily held NOS in their classrooms (Akerson & Volrich, 2006). In that point, Lederman (1999) argued that internalizing the importance of NOS plays an important role in teachers' willingness to teach about NOS. The translation of NOS by teachers into classroom practice is dependent to many factors such as intention to teach NOS, new teachers' fear about classroom management, self-confidence, and administrative restraints (Abd-El- Khalick, Bell, & Lederman, 1998). As teachers' role on developing students' NOS understanding becomes more important, some institutions started to establish standards for science teachers (Irez, 2006). For instance the Association of the Education of Teachers in Science (AETS) Ad Hoc Committee on Science Teacher Educator Standards in the US developed standards that aim to clarify a successful science teacher's framework for the skills, knowledge, and experiences (Irez, 2006):

> Standard 1.d. The beginning science teacher educator should possess levels of understandingof the philosophy, sociology, and history of science exceeding that specified in the reform documents. (p. 236)

In order to convey students' appropriate conceptions of NOS, American Association for the Advancement of Science's (1993) 'Benchmarks for Science Literacy' asserts that, especially teachers should possess adequate conceptions of the scientific enterprise. In addition, a science teacher educator should not only have an informed view of NOS and held NOS in his/her lessons, but also be aware of alternative viewpoints held by other respected professionals and improve him/herself (Irez, 2006).

It is believed that teachers' conceptions and ideas are conveyed whether directly or indirectly to students (Lederman, 1992).However, most of the studies that have been done for more than 40 years showed that teachers and students possess inadequate understandings of NOS (Lederman 1992). For instance, it was found that many teachers thought scientific knowledge is not tentative (Pomeroy, 1993) and some hold a positivistic view of science (Lederman 1992). Although there is a consensus on theory laden aspect of NOS, most teachers still have naïve view of NOS that they held activities in class with collecting theory free data and analyzing them supposedly. Therefore, the teachers expect students to draw obvious conclusions and reach the expected results.

Furthermore, teachers also had some misconceptions about NOS aspects prior to interventions according to research (e.g., Abd-El-Khalick, 2001; Akerson et al., 2000; McComas, 1996). One of the most important misconceptions of the pre-service and in-service teachers is the existence of a single scientific method and a hierarchical view of scientific knowledge (McComas, 1996). As the teachers still believe that scientific knowledge is derived from scientific method, they still continue their students to memorize the steps of this method and make them stay in this rigid lines (Abd-El-Khalick, 2012). For example, they ignored inferential NOS that they believed something must be seen in order to know its meaning; theories are the weaker forms of laws and when science finds the answer, it doesn't change, so they ignored the role of imagination and creativity (Akerson, Morrison & McDuffie, 2006). From that end, it is suggested for both pre-service and in-service teachers to avoid the following incorrect ideas about NOS (McComas, 1996, p.10):

Myth 1: Hypotheses become theories that in turn become laws.

Myth 2: Scientific laws and other such ideas are absolute.

Myth 3: A hypothesis is an educated guess.

Myth 4: A general and universal scientific method exists.

Myth 5: Evidence accumulated carefully will result in sure knowledge.

Myth 6: Science and its methods provide absolute proof.

Myth 7: Science is procedural more than creative.

Myth 8: Science and its methods can answer all questions.

Myth 9: Scientists are particularly objective.

Myth 10: Experiments are the principal route to scientific knowledge.

Myth 11: Scientific conclusions are reviewed for accuracy.

Myth 12: Acceptance of new scientific knowledge is straightforward.

Myth 13: Science models represent reality.

Myth 14: Science and technology are identical.

Myth 15: Science is a solitary pursuit (McComas, 1998).

This brings us to the claim that the curricular, instructional methods or science teacher education in this area have been ineffective (Lederman 1992, McComas 1998). Therefore, there are many attempts to improve pre-service science teachers' NOS views in science methods course contexts (Morrison, Raab, & Ingram, 2009).

There were many studies in the literature focusing pre-service science teachers' NOS views (Cavus, Dogan & Gungoren, 2012). For example, in Meichtry's (1995) study, pre-service teachers' NOS understandings were assessed before, during and at the end of elementary science method course. Students' were handled different activities to develop adequate understanding of NOS. She found that before method course, pre-service teachers' had incomplete understandings of NOS, but after they attended these courses they developed their understanding of NOS. Meichtry (1995) also found that pre-service teachers' ideas had changed when they were asked their ideas on NOS and encouraged to change the wrong ones.

More specifically, in Aguirre, Haggerty and Linder's study (1990), 74 pre-service science teachers' NOS understanding, both teaching and learning, were evaluated by case study approach. The results showed that most of the pre-service science teachers believed that science consists of the observations, explanations and propositions that are proven to be correct. Nearly one-third of the pre-service teachers' characterized learning as getting the knowledge from outside. At the end of the study, the researcher concluded that pre-service science teachers do not have adequate understanding of NOS and there is a connection between teachers' understanding of NOS and their learning and teaching.

Abd-El-Khalick and Lederman (2000b) also conducted a study with college students and pre-service teachers. They were exposed to History of Science (HOS) courses in order to assess its effectiveness to increase college students and pre-service teachers' NOS understanding. Similar to most of the other studies participants' held naïve views at the beginning of the study. However, the results were not so different at the end that there was a little change in students' and pre-service teachersNOS understandings.

Similar studies were also conducted in Turkish context. For example, Yakmaci (1998) hold a study with 18 selected items from Views on Science-Technology-Society (VOSTS) to assess the NOS understandings of pre-service science teachers' in Turkey. The results showed that pre-service science teachers' have contemporary views in the aspects of tentativeness and scientific approach of NOS. However, they have unrealistic views in some points, such as definition of NOS, the difference between observation and inference and in some other characteristics.

Similarly, Erdogan, Cakiroglu and Tekkaya (2007) investigated the Turkish pre-service science teachers' views of the nature of science by using Turkish version of Views on Science-Technology-Society (VOSTS). The results revealed that pre-service teachers held many traditional (naive) views, but they had some views that were consistent with contemporary (realistic) views of the nature of science. The results also showed that science curricular materials and instructional approaches are not sufficient for reflecting the nature of scientific knowledge because of still having traditional views.

In another study, Yalvac and Crawford (2002) studied with 25 graduate and undergraduate science education students in Middle East Technical University (METU) to explore their understandings of NOS. They used an adapted version of a questionnaire (e.g. Schwartz, Lederman, & Crawford, 2000) in their study. Their findings showed that most of the participants hold logical positivism view of NOS. The result showed more than half of Turkish students believe theories change but laws do not change.

Moreover, Bilican, Cakiroglu and Tekkaya (2009) investigated a study with ten prospective science teachers in order to examine the effects of some variables on their teaching nature of science. They studied the impact of microteaching activities, the importance of teaching nature of science, their preferences to teach nature of science and their beliefs about owns' efficacy. The results showed that explicit reflective NOS instruction improved their NOS understandings. However, micro teaching activities provided participants to internalize NOS aspects more deeply and to get the rationale discovering different ways to teach NOS.

In a recent study, Mihladiz and Dogan (2012) conducted a study with 89 pre-service science teachers' in order to determine pre-service science teachers' NOS understanding. They found that pre-service science teachers' have enough adequate understanding about tentativeness of scientific knowledge, scientific approach for researches and public influence on scientists. However, they have insufficient understanding about theory vs. law aspect and nature of scientific models of NOS.

Like pre-service science teachers, many studies were conducted with in-service science teachers to improve their NOS views and to examine their instructional practice in their classes. For example, Abd-El-Khalick and BouJaoude (1997) conducted a study with 20 in-service science teachers to investigate if there is a relation between teachers' knowledge base with their level of education, years of teaching experience, and the class levels that they teach. They described the knowledge base of science teachers in terms of their knowledge of the structure, function, and development of their disciplines, and their understanding of NOS. Teachers were applied the modified version of The Views on Science-Technology-Society (VOSTS) questionnaire, interviewed and desired to construct concept maps to assess their understanding of NOS. After the teachers' concept maps, interviews and VOSTS questionnaire results were analyzed, it was found that teachers had some naïve views about NOS and its disciplines. In addition, the results showed that knowledge base including NOS did not relate to their years of teaching experience, the class levels that they teach, and their level of education.

In another study, Abell, Martini and George (2001) planned to conduct a different experiment in a science method course with 11 elementary education teachers. For the investigation, participants were desired to observe the moon during the course and record their observations. From that experiment, the researchers targeted the participants to understand empirically based, invention and explanations, socially embedded aspects of NOS. After the investigation, elementary education teachers realized that scientists make observations, they were able to differentiate the observation and creating explanations, but they could not see the connection between what they learned from the activity and the scientific community. From that result, the researchers recognized the importance of explicit NOS instruction, because participants couldn't make an explicit connection between the activities they did in class and what the scientists did.

In Turkey, Dogan and Abd-El-Khalick (2008) also examined the relationship between 10^{th} grade students' and science teachers' conceptions of NOS and selected variables including gender, geographical region, and the socioeconomic status (SES) of their city and region; teacher disciplinary background, years of teaching experience, graduate degree, and type of teacher training program; and student household SES and parents' educational level. A total of 2,020 students (97%) and 362 teachers (96%) completed the "Views on Science-Technology-Society" (VOSTS) questionnaire. The results showed that teachers' views were not so different from their students' and majority of participants held naïve views of target

NOS aspects. It was also reported that teachers' and students' views of some NOS aspects were related to some of the target variables.

2.1.3. Teaching and Learning of NOS

Different approaches provide teachers to develop their views of several important aspects of NOS in different levels of success (e.g. Abd-El-Khalick & Lederman, 2000a). Although there is no accepted single method course that achieves a substantial change in elementary teachers' NOS conceptions, they provide support to develop their NOS understanding (Shapiro, 1996).

Learning about NOS should be planned carefully to develop science content or science process skills. On the implementation of NOS teaching in classroom Lederman (1995) states that the initial focus must be on promoting the internalization of the view that the nature of science is an important instructional objective which must be considered during the development and implementation of every instructional process. In this context, Abd-El-Khalick and Lederman (2000a) identified two general approaches, which are "implicit" and “explicit”, to find the most efficient and productive way of improving pre-service and in-service science teachers' views about NOS.

2.1.4. Implicit NOS Instruction

“Implicit” approach is whether derived from the assumption that teachers' understandings of NOS are a "by-product" or a natural consequence of engaging teachers with the "doing" of science (Abd-El-Khalick & Lederman, 2000a).

The ineffectiveness of implicit approach can be seen from the investigations that its underlying reason can be inferred and made assumptions. One of the assumption is that learning about NOS should be an effective learning outcome that students' NOS conceptions can be developed better by using engagement in science based inquiry activities and science process skills instruction (Abd-El-Khalick & Lederman, 2000a). In other words, when NOS aspects are directly addressed, students improve the specific conceptions of NOS (Abd-El-Khalick & Khishfe, 2002).

In implicit approach, learning NOS is a secondary outcome that arises while learning other science concepts, so there is no need to emphasize NOS concepts (Abd-El-Khalick & Lederman, 2000b; Lederman et al., 2001). However, many studies showed that the implicit approach was not effective to have students informed view of NOS (Abd-El- Khalick & Khishfe, 2002). Although their number of samples was different, their results were the same that implicit approach was not effective on students to develop their NOS understanding (Abd-El-Khalick & Khishfe, 2002). For example,

Meichtry (1992) conducted a research with 1004 elementary students about the effect of implicit approach on NOS teaching. She found that experimental group students' understanding of developmental NOS decreased relative to comparison group. Therefore, she pointed out that implicit approach did not have an impact on student understandings of NOS, so there is a need for explicit representation of NOS aspects in science content (Meichtry, 1992). In a different study, Moss et al. (1998) also investigated the implicit approach on 11th and 12th grade students' NOS understanding by engaging inquiry oriented projects. Moss et al. (1998) reached same results with other similar investigations. The results showed that students did not have a developed understanding of NOS at the end of the research.

2.1.4.1. Explicit Reflective NOS Instruction

The second and the more effective approach is "explicit" approach. The assumption of this approach is to facilitate teachers' NOS views by designing programs around themes and aspects of NOS from history and philosophy of science (Abd-El-Khalick & Lederman, 2000a). Akindehin (1988), who was advanced this approach later, asserted that if it is desired to help science teachers to develop their understanding of NOS, these attempts should be explicit. Implicit approach's NOS outcomes are more as attitudinal or dispositional in nature, on the other hand explicit approach's outcomes are more as cognitive instructional (Abd-El-Khalick & Lederman, 2000a).

Afterwards, "explicit" approach is enlarged to include an important aspect which is "reflection" by Abd-El-Khalick et al. (1998) and Akerson, Abd-El-Khalick, and Lederman (2000). Therefore, "explicit-reflective" approach was born, which implies 'explicit' is curricular in nature while the label 'reflective' has instructional implications. In "explicit reflective" instruction, explicit does not refer to didactic or explicit teaching strategies, it requires the importance of NOS understanding which is a cognitive outcome, so it should be addressed and targeted intentionally (Khishfe & Abd-El-Khalick, 2002). Reflective component is provided by the instructor with questions or prompts embedded within science learning activities and reflection papers about NOS related articles (Abd-El- Khalick, 2001; Khishfe & Abd-El-Khalick, 2002). In explicit reflective NOS instruction, teachers introduce NOS explicitly, and then they provide different activities which students engaged in and reflect their ideas and understandings about NOS aspects (Lederman & Abd-El-Khalick, 1998). Therefore, explicit- reflective approach is student-centered and embeds science content and inquiry-oriented experiences in it (Abd-El-Khalick, 2001; Abd-El-Khalick & Akerson., 2004).

It may be derived from insufficient context of explicit teaching that it should include more efficient activities which are directly linked to science content (e.g., Brickhouse, Dagher, Letts, & Shipman, 2000; Clough, 2003; Ryder, Leach, & Driver, 1999). Therefore, an explicit reflective approach involves teaching NOS purposefully requiring discussion, guided reflection, directed questioning and science activities (Schwartz, Lederman, Khishfe, Sweeney Lederman, Matthews & Liu, 2001). In addition, Abd-El-Khalick and Akerson (2004) showed that pre-service teachers' NOS understandings developed at the end of having explicit reflective science method courses.

Abd-El-Khalick and Lederman (2000a), Abd-El-Khalick (2001) and Khishfe and Abd-El-Khalick (2002) conducted studies to find out the effectiveness of either implicit or explicit approach. The general result of the studies showed that an explicit approach has better implications compared to employing implicit approaches and the idea was accepted that explicit approach was relatively more effective in enhancing science teachers' understandings of NOS (Abd-El-Khalick & Akerson, 2009).

Moreover, Akerson et al. (2000) examined the effectiveness of this approach on 50 pre-service elementary teachers, dividing them into two sections. In one of the class, discussions and written reflections including prompts related to NOS was applied, in other class implicit approach was used. As a result of the study they concluded that the explicit-reflective, activity-based NOS instruction employed in the science methods course was effective in enhancing pre-service elementary teachers' views of NOS.

In another study, Abd-El-Khalick and Akerson (2004) conducted a study in science method course with 28 pre-service elementary teachers. They examined effectiveness of explicit reflective instruction on pre-service science teachers' views of various NOS aspects. They analyzed the outcomes of questionnaires, interviews and reflection papers of participants. The majority of participants held naïve views at the beginning of the study, but the results showed that their views were increased favorably.

Schwartz et al. (2004) also reached the same result and provided additional support that explicit and guided attention and reflection on NOS enhances student and pre-service teacher understanding of NOS.

In a similar study, Akerson, Morrison, and McDuffie (2006) made an investigation with 17 master degree students in their science teaching method course. At the beginning of the year Views of Nature of Science, Form B (VNOS-B; Bell, Blair, Crawford, & Lederman, 2003) questionnaire was used to measure their understanding of NOS aspects. Then, on the continuing 5 months the instructor used explicit reflective NOS instruction as a treatment. During five months students (a) had weekly readings including NOS related parts, (b) performed weekly hands-on activities, by making explicit references to NOS, to facilitate their key scientific concepts, (c) engaged in 6 hours instructional activities aimed to emphasize seven target aspects of NOS and (d) did oral and written writings which they reflect their NOS understandings. After five months students answered VNOS-B questionnaire again. Results of the study showed an improvement in pre-service teachers' understanding of NOS. However, they could not internalize these concepts, because after five months the participants' understanding of NOS decreased to their prior views. Therefore, Akerson et al. (2006) analyzed the cognitive levels of participants and concluded that metacognitive teaching strategies could be useful for pre-service teachers to not only develop their NOS understandings, but also internalize it.

In Turkish context, Kucuk (2008) conducted a study in science, technology and society course with twelve pre-service elementary science teachers. The explicit reflective NOS instruction was used to improve the pre-service science teachers' understanding of NOS. Data were collected through Views of the Nature of Science-form C (VNOS-C) survey and semi-structured interviews both at the beginning and at the end of the intervention. Results showed that majority of the participants' understandings of all the NOS aspects improved, except for relationship and distinction between theories and laws.

A similar study was conducted by Yalcinoglu and Anagun (2012). A total of 29 pre-service science teachers involved in NOS activities developed by Lederman and Abd-El-Khalick (1998) and classroom discussions after each activity. The majority of participants held naïve views of NOS at the beginning of the study. However, at the end of the study, the participants had substantial gains in theory laden, social and cultural and theory vs. law aspect of NOS.

Different from pre-service science teachers Koksal (2010) conducted a study in order to find the effect of explicit embedded reflective approach on nine grade students' understanding of NOS, scientific literacy levels and achievement on cell unit. In the study, explicit embedded reflective teaching was used in intervention group. However, NOS instruction was conducted through lecture, demonstration and questioning strategies in the comparison group. The result showed that, explicit embedded reflective teaching was more effective on learning cell content knowledge and NOS understandings than common approach in comparison group.

As it can be understood from the review of important studies in science education literature, NOS is an important component of scientific literacy. There have been several studies that were investigated to develop the understanding of NOS knowledge. Parallel with this idea there have been conducted many NOS studies in Turkey.

2.2. Defining Metacognition

The other important tool for this study is metacognition which is handled as metacognitive strategies in this study.

The term "metacognition" was used formally for the first time by John Flavell in 1976, that the term has often been associated with him (Zulkiply, Kabit & Ghani, 2008). He defined metacognition as follows: "In any kind of cognitive transaction with the human or non-human environment, a variety of information processing activities may go on. Metacognition refers, among other things, to the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data on which they bear, usually in service of some concrete goal or objective." (Flavell, 1981, p.232).

Metacognition was originally referred to as the knowledge about and regulation of one's cognitive activities in learning processes (Flavell, 1979; Brown, 1987). Metacognition is the continuum of self-regulation that manages and directs functions of controlling actions or recognizing thinking process and evaluating them (Weinert, 1987). In the light of these inclusive definitions, the increase of metacognitive terms has unfolded through years. Metacognitive beliefs, metacognitive awareness, metacognitive experiences, metacognitive knowledge, feeling of knowing, judgment of learning, theory of mind, metamemory, metacognitive skills, executive skills, higher-order skills, metacomponents, comprehension monitoring, learning strategies, heuristic strategies, and self-regulation are several of the terms that are commonly associated with metacognition (Veenman & Hout-Wolt & Afflerbach, 2006). Metacognition provides improved learning that students became aware of their own capabilities with their insights and their learning repertoires (Brown, 1994). Are you sure if you could remember the subject next week that you have studied during the day or are you sure if you could solve the similar problems in the exam that you solved while studying? All these questions' answers take part in the definition of metacognition (Mazzoni & Nelson, 1998)

Flavell (1979) divided the metacognition into four classes namely metacognitive knowledge, metacognitive experiences, tasks and goals, and strategies or actions.

Metacognitive knowledge has three variables which are person, task and strategy (Flavell, 1987). The person variable is also subdivided into three variables. *Intra- individual variable* refers to knowledge or beliefs about the interests, propensities, aptitudes, abilities, and the like, of oneself or of another person; *Inter-individual variable* compares between and among persons in a relativistic manner. *Universal variable* means the universal aspects of human cognition and psychology. *Task variable* of Flavell (1987) refers to the persons' different and various tasks that they learn from their implications. People gain personal experience according to the difficulty level of these tasks. Different kinds of information lead to different kinds of understanding, processing and different demands. Task knowledge informs the person about the possible outcomes of the task and related goals to its completion (Flavell, 1979). The last variable which is *strategy* refers to person's goals or objectives and the selection of them during the learning process. Flavell (1979) emphasized that these variables overlap and the person use their combinations or their interactions according to the situation.

Metacognitive experiences provide internal feedback about the current progress, future expectations of progress or connecting new information to old.

Therefore, metacognitive experiences require a person's internal responses to his own metacognitive knowledge, goals or strategies (Flavell, 1979)

The third category of Flavell (1979) which is goals and tasks refers to desired or aimed outcomes of cognitive processes. The last category metacognitive strategies are the monitoring tools for cognitive progresses (Flavell, 1979). This is a type of control progress to check if the cognitive goals such as understanding the reading texts, solving the problem have met or not. If a person has good metacognitive skills and is aware of them, he can oversee his learning process, plan and monitor ongoing cognitive activities and evaluate it with expected outcomes (Flavell, 1979).

Metacognition refers to a person's declarative knowledge about the interactions between person, task, and strategy characteristics (Flavell, 1979), while metacognitive skills refers to a person's procedural knowledge for regulating one's problem solving and learning activities (Brown & De Loache, 1978; Veenman, 2005).

There has been general and continuing agreement among researchers that metacognitive knowledge and skills can be taught, and that such training often results in substantial improvements in learning and achievement (e.g., Brenna, 1995; Mayer & Wittrock, 1996; Palincsar & Brown, 1984; Smith, 1994). People could select and invent strategies explicitly via thinking the aims of the task, their cognitive resources or experiences when they have the similar situations, that shows metacognitive knowledge can be verbalized, it can be accessed and modified through reflective mechanisms (Crowley, Shrager, & Siegler, 1997).

There are four main types of strategic knowledge which are major for students to think in a metacognitive manner (Hartman, 2001; McCormick, 2006; Schraw & Dennison, 1994). These components include (a) planning, which helps the learner define what the problem is, and select an appropriate solution strategy, (b) monitor the effectiveness of the solution strategy, and (c) regulate themselves while learning in order to identify and overcoming obstacles to solving the tasks in front of them and (d) evaluating the end results. These four key components and the elements they include are shown in Table 2.3.

Table 2.4. Key Metacognitive Elements

Constructs	Indicator Behaviors
Planning	1. Making predictions 2. Being aware of what is already known so appropriate strategies can be selected 3. Sequencing those strategies 4. Allocating time and attention that affect performance
Monitoring	1. Identifying the task 2. Checking one's on-line awareness of comprehension and task performance 3. Deciding whether, in light of new information, a path already taken should be abandoned and what, if anything, can be salvaged from an abandoned attempt 4. Looking for previously overlooked information and identifying ways to combine information 5. Predicting the eventual outcome 6. Engaging in periodic self-testing
Regulating	1. Allocating resources and number of steps needed to complete a task 2. Being mindful of the intensity and speed with which a task must be completed 3. Using existing strategies to the learner's best advantage 4. Increasing awareness of comprehension breakdowns
Evaluating	1. Determining the efficacy of one's efforts 2. Self-reflective thinking about experiences and situations to determine if knowledge is adequate 3. Determining what goals are to be set in light of one's self-efficacy

Excerpted from "Effect of Prompted Reflection and Metacognitive Skill Instruction on University Freshmen's use of Metacognition", Erskine, 2009, p.12

According to Hobson (2008) the importance of metacognition can be listed simply as follows;

- It provides knowledge of when and where to use acquired strategies.
- Knowledge about one's thinking includes information about one's own capacities, limitations and awareness of difficulties as they appear during learning, so metacognition serves remedial action.
- It offers an alternative to traditional methods of teaching

In a more recent study Lai (2011) concluded that; (1) metacognition is related to other constructs such as critical thinking (e.g. Flavell, 1979; Martinez, 2006), motivation (e.g. Cross & Paris, 1988; Ray & Smith, 2010; Whitebread et al., 2009), and metamemory (e.g. Schneider & Lockl, 2002); (2) metacognitive abilities improve with age (e.g. Hennessey, 1999; Schneider, 2008; Schraw & Moshman, 1995); (3) metacognition can be taught (e.g. Cross & Paris, 1988; Kramarski & Mevarech, 2003). Besides that there is an agreement in the literature on the importance of metacognition in improving students' thinking and learning (Ben-David, & Orion, 2012)

On the other hand, there are many claims that metacognition has some limitations. According to Jacobs and Paris (1987) although metacognition is believed to focuses on thinking, reflecting, and strategic planning, it leads to copious amount of drills on cognitive skills that are not embedded within the context of reading. In addition many instruments that are used to measure metacognition can sometimes prove to be boring, complex and lacking in validity. Therefore, measuring metacognition may be challenging, difficult and includes many criticisms (Gay, 2001).

2.2.1. Components of Metacognition

Metacognition is based on the argument that it has two components (Schraw & Dennison, 1994). These two components are knowledge of cognition (KoC) and regulation of cognition (RoC). They also claimed that these two components are interrelated and intercorrelated that they both help students to self-regulate (Schraw & Dennison, 1994).

Henri (1992) called these two components as knowledge and skills that he drew a model of Flavell's (1987) strategy, person and task variables. While Flavell (1987) called them as knowledge and experiences; Jacobs and Paris (1987) called as self-appraisal of cognition and self-management of thinking.

Metacognition may have some boundaries, so some key distinctions can be made to organize and assess the experimental literature (Louca, 2008). According to Flavell (1981) the most common distinction in metacognition separates metacognitive knowledge from skills. Metacognitive knowledge is related with knowledge about the cognitive system, while metacognitive skills deal with the regulation of cognitive processes (Vennman, 2012). This is the difference between like "knowing that" and "knowing how" theory and practice or performance and competence (Louca, 2008). Metacognitive knowledge is the acquired world knowledge of the person with cognitive matters. It can be categorized as declarative, procedural and conditional knowledge. Declarative knowledge is using cognitive processes to express facts and opinions, procedural knowledge is knowing how to perform cognitive strategies and conditional knowledge is knowing when and why to use them (Flavell, 1981). Metacognitive knowledge about our learning processes may be quite resistant to change even if it is either correct or incorrect (Afflerbach, Veenman & Wolters, 2006).

In the literature two kinds of metacognitive skills have been described; knowledge of cognition which consists of a person's cognitive processes including strengths and weaknesses while learning, knowledge about strategies and when and where to use them; regulation of cognition refers to person's performance of planning, monitoring and correcting while learning (Schraw, 1994, p. 143). Although a person cannot plan his actions and task performance, he/she should ensure that metacognitive skills are developing. Gaining metacognitive skills take time and effort that sometimes it may fail and provide a new metacognitive knowledge (Afflerbach, Veenman & Wolters, 2006).

Knowledge of cognition (KoC) refers to what learners know about their cognition and the way they learn (Sperling, Howard, Staley & Dubois, 2004). It has three subcomponents. *Declarative knowledge* refers to knowing ourselves as learners and knowing what affects our performance. *Procedural knowledge* refers to knowing which one and how to use strategies such as note taking, listening carefully, and underlining important parts of the text to understand better. *Conditional knowledge* directs us when and why to use these strategies according to the situation. If a person has a good conditional knowledge, she/he can select the best strategy at the right time for a high quality of learning (Schraw & Dennison, 1994). Studies indicated that children with high metacognitive knowledge get higher scores on ability tests than children with low metacognitive knowledge (Swanson, 1990). In addition, KoC has an important effect on university students' decision making that KoC should be explicit to be useful, but implicit in some situations (Butler & Winne, 1995; Batha & Carol, 2007).

Regulation of cognition (RoC) includes planning, monitoring and evaluation (Schraw & Moshman, 1995). *Planning* refers to select appropriate strategies and allocate resources to achieve desired outcome. *Monitoring* is an on-line awareness and checking comprehension and task performance. *Evaluation* is the appraisal of the learning outcome and efficiency of one's learning (Brown, 1980).

There are many claims that knowledge and regulation components are interdependent (Sperling, Howard, Staley & DuBois, 2004). Knowledge of cognition is the better predictor of performance on understanding a reading text than regulation of cognition that KoC precedes RoC (Schraw & Dennison, 1994). For instance, if you are not successful on a certain task, you will monitor yourself more carefully. If you find too many errors while monitoring, you conclude that the task was difficult or you were not successful (Panaoura, Philippou & Christou, 2003). On the other hand, some studies showed that there is no strong relation between KOC and ROC (e.g., Dennison, 1996; Tobias, Everson & Laitusis, 1999).

2.2.2. Metacognitive Strategies

Metacognitive strategies are the techniques that increase the awareness of individual's thought processes while completing the tasks (Jansiewicz, 2008). Therefore, it is important to understand and use different components of metacognition for processing information (Stuever, 1997). The first step of getting new information is to connect it with the previous one for determining the level of understanding (Blakey & Spence, 1990; Hacker, 1998; McCormick & Pressley, 1997). Then, in second step individuals should select and regulate effective strategies to facilitate the task (Blakey & Spence, 1990; Hacker, 1998; McCormick & Pressley, 1997; Olsen, 1990).

Before analyzing the metacognition deeply, its most important effects, which are awareness, planning and monitoring and reflection, on learning should be considered to understand metacognitive strategies better (Ridley et al., 1992). Awareness consciously identifies what you already know, defines the learning goal, considers your personal resources and the task requirements, and determines how your performance will be evaluated. Planning serves to organize materials, estimates the time required to complete the task, plans study time into your schedule and sets priorities. Finally, monitoring and reflection provide to reflect on the learning process, keep track of what works and what doesn't work for you, monitor your own learning by questioning, and do your own feedback (Ridley, Schutz, Glanz & Weinstein, 1992; Grabinger, 1996).

Awareness, planning and monitoring and reflection requires some questions to provide self-questioning. (Excerpted from Strategic Teaching and Reading Project Guidebook, 1995, NCREL, rev. ed.).

Before formulating the strategy; when *developing* the plan of action, self-talk is essential:

1. What in my prior knowledge will help me with this particular task?
2. In what direction do I want my thinking to take me?
3. What should I do first?
4. Why am I reading this selection?
5. How much time do I have to complete the task?

During the execution of the strategy; when you are *maintaining/monitoring* the plan of action, ask yourself:

1. How am I doing?
2. Am I on the right track?
3. How should I proceed?
4. What information is important to remember?
5. Should I move in a different direction?
6. Should I adjust the pace depending on the difficulty?
7. What do I need to do if I do not understand?

After the task is accomplished; when you are *evaluating* the plan of action ask yourself:

1. How well did I do?
2. Did my particular course of thinking produce more or less than I had expected?
3. What could I have done differently?
4. How might I apply this line of thinking to other problems?
5. Do I need to go back through the task to fill in any "blanks" in my understanding?

Metacognitive strategies are very important because as students become more skilled at using metacognitive strategies, they gain confidence and become more independent as learners (Brown et al., 1983; Flavell et al., 2002; Livingston, 1997). Independence leads to ownership as students realize they can search their own intellectual needs and discover a world of information at their fingertips.

Lodico et al. (1983) showed in his study that the children who were taught to monitor the use of effective strategy did better performance on tasks. In addition metacognitive strategies provide students to find and reflect the ways to understand the target content deeply (Schraw, 1994). Especially self-regulated metacognitive strategies improve recall and retention of science content knowledge (Spiegel & Barufaldi, 1994). Also, using several strategies rather than a single strategy and being taught within the context of specific subject matter are more effective for metacognitive training (Brown & Palinscar, 1987; Mayer & Wittrock, 1996; Pressley, El-Dinary, Marks, Brown, & Stein, 1992).

One of the most taught and used metacognitive strategies are reading comprehension strategies that students could practice it alone or in groups. During these process students take active role, she/he can maintain or switch the strategy while reading. Reading comprehension strategies focus on and require high cognitive functioning (Jansiewicz, 2008). In this approach, the teacher may ask which strategy was used in different parts of reading and what the thoughts were during the process. From this end, subjective experience of the reader can get, but it is difficult to measure if the used strategy was the actual one or not (Burke, Smith & Imhoff, 1989).

The other most used strategy is think-aloud strategy. In Baumann et al. (1993) study, think alouds were applied by various strategies such as asking questions, drawing on prior knowledge, assessing comprehension, predicting, verifying, retelling, rereading for clarification. It was concluded that think alouds were helpful for students to gain and improve such qualifications that are making inferences, understanding characterization understanding the main ideas. Teachers' one of the most important roles is to model how a reader might think about ideas in a text by using think alouds (Beck et al., 1996). Therefore, students can easily see in a first-hand manner that how an expert reader gain meaning from reading (Back et al., 1996).

One of the other metacognitive strategies is concept mapping. It is described as a “metacognitive tool” that provides students to think their understandings reflectively by visual representation of their concept meanings and relationships (Mintzes, Wandersee & Novak, 1997; Cassata & French, 2006). Concept mapping instruction improves college students’ (August-Brady, 2005), high school students’ (Chularut & DeBacker, 2004), and primary school students’ (Stow, 1997) self-reflection and strategic action (Cassata & French, 2006). Students could make decisions about different concepts and reflect on their prior knowledge relating to new one by creating and modifying a concept map (McAleese, 1998). As the maps are constructed, students engage in “control” processes of planning, monitoring progress, and evaluating goal attainment (Brown, 1987). In Patry’s (2004) study, students in physical science course trained by concept map method in short term. Experimental group students were explained for 75 minutes initially, and then they were instructed 45 minutes sessions five times in two months, control group students’ get them in four months. At the end of that short term experiment, it was found that concept mapping had no clear effect on the development of metacognition. Although concept maps are beneficial for students to improve their mindful reflection and facilitate self-regulated learning, the implemented instructional procedures affect its success directly (Cassata & French, 2006).

According to Vygotsky (1986) if you want to subject a function intellectually, you should process it. This means that self-reflection must develop as a skill before it become to be used as a series of consciously controlled strategies (Downing et al., 2009). In that point, social interaction and relationship play an important role. The social interaction for training reflective skills is an approach in instruction such as peer teaching that force teachers to use most of the metacognitive strategies such as determining what the learner knows, deciding what and how to be learnt, monitoring the process and evaluating the outcome (Wright, 1991). Social constructivists claim that metacognitive processes firstly emerge as social processes and then become internalized (Downing, 2001).

In Turkish context, Sungur and Senler (2009) investigated a study with 141 Turkish high school students about their metacognition and its relation to achievement goals. Metacognition was examined in terms of KoC (declarative knowledge, procedural knowledge, and conditional knowledge) and RoC (planning, information management, monitoring, debugging, and evaluating). The results showed that Turkish students have more declarative and conditional knowledge than procedural knowledge and mostly use debugging strategies. Rather than threat, all other motivational factors positively affect students' metacognition.

In a different study, Kahraman and Sungur (2011) conducted a study with 115 elementary school students about the contribution of motivational beliefs to students' metacognitive strategy use. The results demonstrated that the students, who have self-efficacy and study science for learning and understanding, have more tendencies to use metacognitive strategies.

From all these strategies, in the present study three metacognitive strategies were used: concept mapping (Novak, 1990; Novak & Gowin, 1984), researching the development of the ideas of peers (Oldfather, 2002), and responding to case studies (Thomas & Barksdale-Ladd, 2000). In addition, these strategies are embedded in NOS instruction on pre-service science teachers' understanding of NOS.

2.2.3. Nature of Science as a Metacognitive Resource

An American travels to France, but he eats only fast food. After he returns to his country, he mentions in a skewed view that France foods are not diversified, because finding a French restaurant that he desired was difficult (Peters, 2006). As it is illustrated in the metaphor of travel, if a teacher has limited teaching process skills, didactic teaching becomes inevitable which is fast food. However, students need to understand science deeply rather than a rote understanding (Peters, 2006). Teaching NOS by didactic, disconnected and implicit, led students not to access the important connection between scientific knowledge and knowledge about science (Abd-El-Khalick & Akerson, 2004).

There is a general agreement that traditional methods of teaching do not provide students to show all their knowledge about science (Driver, Newton & Osborne, 2000). This comes from the change that NOS has been taught as content rather than epistemology. In that point NOS aspects would be helpful for students to think about the epistemology and the rationale in forming ideas (Duschl, Hamilton, & Grandy, 1992). It is beneficial for teachers to make students examine the information they know and think about how student knowledge is scientific (Peters, 2007). However, the subject of students learning of NOS needs more explorations that there should be more connection between the scientific community and science teachers (Glasson & Bentley, 2000), more understanding of student views of the nature of science (Zeidler et al., 2002), and more understanding of how teachers who have a sophisticated view of the nature of science can incorporate these ideas into classroom practice (Peters, 2007). In that point, it can be mentioned about some measurably successful suggestions that provide deeper understanding of NOS (Akerson & Abd-El-Khalick 2003; Beeth & Hewson, 1999; Davis, 2003). For instance, metacognition that provides to validate knowledge and encourage teachers to develop NOS is a method for teaching the epistemology of NOS. Metacognition avoids teachers to be depersonalized, context-free, and mechanistic view of teaching help students to get science disciplines and changing guidelines (Doyle, 1990).

However, there are only a few studies that incorporate metacognitive strategies into classroom practice in order to develop nature of science views of students', pre-service science teachers' or in-service science teachers'. For example,

Peters (2007) conducted a study with 88 eight grade students in order to find the effectiveness of metacognitive prompts on science students' content and nature of science knowledge, metacognition and self-regulatory efficacy. He investigated an experimental study that he assigned the students to an experimental and control group. Students were applied five pre and post tests about content and NOS knowledge and surveys about metacognition of the nature of science, metacognitive orientation of the classroom, and self-regulatory efficacy. It was desired the experimental group get higher scores than control group. The results showed that there was a partial support for the hypothesis that there was significant gain in content knowledge and nature of science knowledge of the experimental group over the control group.

In another study, Abd-El-Khalick and Akerson (2009) investigated an experimental research with 49 pre-service elementary teachers in science method course. The study had a pre-test and post –test quasi experimental design. Participants were divided into two as intervention and comparison group. Both groups had explicit reflective NOS instruction, however, only intervention group had some training in and used metacognitive strategies during the course. The aim was to evaluate pre-service science teachers'understanding of NOS aspects and their metacognitive awareness by using the Views of Nature of Science Questionnaire—Form C (VNOS-C) (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) and the MAI (Schraw & Dennison, 1994). The results showed that there was a significant increase in intervention group's MAI scores, but there was no significant change in comparison groups' MAI scores. VNOS-C results indicate that participants' view of all five target of NOS aspects were not significantly different. However, intervention group's post-test views were significantly higher than the comparison groups views in empirical, tentative, theory driven and inferential NOS, but not significantly different in creative NOS.

CHAPTER III

METHOD

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

This part of the chapter explains the design of the study that the study design and the research questions were addressed. Next, participants, context of the study, data collection and analysis are provided. Validity and reliability issues are presented in data collection and analysis parts and the researcher‘s biases are presented in the end.

3.1. Design of the Study

This study intends to investigate the effect of using metacognitive strategies to improve the NOS understanding of pre-service science teachers. Metacognitive strategies were used by embedding in explicit reflective NOS instruction. These strategies were reflection papers, case studies, researching the development of the ideas of peers and concept maps. The effectiveness was investigated through different questionnaires. The study had a pre-test–post-test, comparison group, quasi-experimental design (Cook & Campbell, 1979; Shadish, Cook, & Campbell, 2002). Specific research questions which guided this study were:

1. What is the effect, if any, of using metacognitive strategies embedded in explicit–reflective NOS instruction on the development of pre-service science teachers' understandings of NOS?
    a. What are PSTs' NOS understandings before the NOS instruction?

b. What are PSTs' NOS understandings after the NOS instruction?

2. What is the effect, if any, of using metacognitive strategies embedded in explicit–reflective NOS instruction on the development of pre-service science teachers' metacognitive awareness?

3.2. Population and Sample

Participants were already formed groups of Elementary Science Education 3rd year teacher candidates at Faculty of Education, Middle East Technical University, Turkey.

Before deciding on the sample, target population was defined. Since this study is aimed to investigate the effects of using metacognitive strategies embedded in explicit reflective NOS instruction on the development of students NOS understanding, the target population of the study is defined as all pre-service science teachers who received NOS instruction in Ankara. As it is hard to reach all pre-service science teachers in Turkey and have such an experimental study on different places, an accessible population of all pre-service science teachers in Ankara is defined.

It was decided to study with 3rd year students of elementary science education departments, because it was important for this study that the students should be having explicit reflective nature of science instruction first time ever. As the researcher was also educated in elementary science education department in METU and knew contents of the courses were convenient to the study; it was decided to conduct this study at METU with 3rd year elementary science education department students.

Elementary science education program at METU accepts 50 students each year. At the beginning of the semester 33 pre-service science teachers (PSTs), 24 were female and 9 were male agreed to join the study voluntarily. These students were selected for this study while they were enrolling at their 5th semester in which they attended *Methods of Teaching Science I* course offered by the faculty of education. These 3rd year science teacher candidates had the same science major background and were having first time ever explicit reflective nature of science instruction. Participants in science methods course were taught in two different sections during the semester. The first section contained 18 participants and second section contained 15 participants. These sections were randomly assigned to groups which were intervention group and comparison group. Both sections met for four hours each week over the course of four months and both groups were taught by the same instructor.

3.3. Context of the Study

3.3.1. The Context of the Study: Methods of Teaching Science I

The major aim of Elementary Science Education (ESE) program is to train pre-service science teachers to understand science in a meaningful way with a good self-image and an outgoing personality. The program aims to give the prospective teachers the idea of how children learn science and how they should educate their students with confident in using technology; capable in problem-solving; attentive to human rights, democracy, and ethics (METU, 2012).

In the first and the second year of the ESE program in METU, the pre-service science teachers complete science coursework in biology, chemistry, physics, and mathematics. In their third years, they enroll the *Methods of Teaching Science I* course with other courses which are directly aimed to develop scientific knowledge.

In *Methods of Teaching Science I* course, pre-service science teachers were enrolled into one of the two sections in fall semester. PSTs in the *Methods of Teaching Science I* course met for four hours each week over the course of one semester. The major subject was NOS in the methods course. In both intervention and comparison groups, an explicit–reflective approach was used to address NOS aspects. PSTs were getting NOS instruction ever for the first time that their views of the target NOS aspects were first derived from analyzing their pre-instruction responses to the VNOS-C questionnaire. Then during the semester, both intervention and comparison groups were engaged in hands-on activities designed to help them examine their NOS understandings. However, intervention group had the lessons with metacognitive strategies embedded in explicit reflective NOS instruction. After each activity, small-group and whole class discussions followed aiming the PSTs to explicitly involve the ideas about NOS (Akerson & Abd-El-Khalick, 2009). Four metacognitive strategies were used in intervention group in the present study which were concept mapping (Novak, 1990; Novak & Gowin, 1984), researching the development of the ideas of peers (Oldfather, 2002), writing two reflection papers about two NOS articles and response to a case study (Thomas & Barksdale-Ladd, 2000).

3.3.2. Aspects of NOS Focused on in the Course

NOS aspects which are identified and agreed on by science educators to be relevant to K-16 education were used in the study (Abd-El-Khalick & Akerson, 2004; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Schwartz, Lederman &Crawford, 2004). The instructor handled all aspects of NOS in both intervention and comparison groups during the semester. These aspects are;

(1)Scientific knowledge is empirically-based that it is based on and/or derived from observations of the natural world.

(2) Scientific knowledge is tentative that it is subject to change with new observations and reinterpretations of existing knowledge. Scientific knowledge is never absolute or certain.

(3) Scientific knowledge is theory-laden that it is partially based on human inference. Scientists' theoretical and disciplinary commitments influence their works (Abd-El-Khalick & Lederman, 2000b, p. 1063).

(4)Scientific knowledge requires observations, inference, and theoretical entities that observations are gathered through human senses but inferences are the interpretations of them.

(5) The relationship between theories and laws that one does not become the other.

(6) Scientific knowledge includes imagination and creativity that human imagination and logical reasoning generate scientific knowledge by the help of observation and inferences of the natural world

(7) Scientific knowledge is socially and culturally embedded that science both affects and is affected from the dimensions and elements of social environment (Akerson, Abd-El-Khalick& Lederman, 2000).

The instructor conducted a set of generic activities incorporated specific aspects of NOS (Abd-El-Khalick, 1998). These activities which were developed by Lederman and Abd-El-Khalick (1998) implemented through the semester both in comparison and intervention groups. Table 2 presents the NOS aspects that were addressed in the context of each activity. Descriptions of eight generic activities appear in Appendix G.

Table 3.1. Aspects of the Nature of Science and Corresponding Generic NOS Activities

Week	Nature of Science Aspect	Activity
1-2	The Empirical, inferential	Tricky track Real Fossils- Real Science
3	Tentative, emprical, imaginative/creative, inferential	The aging president Young? Old?
4	Tentative, emprical, imaginative/creative, inferential	That's part of life!
5	Inferential, imaginative/creative, theory laden	Black Box, The Tube, The Cube

3.3.3. Intervention

PSTs in both comparison and intervention groups held explicit-reflective NOS instruction in which generic NOS activities supported with discussions were used. On the other hand, PSTs in intervention group used different metacognitive strategies. The interventions held in both groups mentioned in Table 3.2.

Table 3.2. Intervention Used in Comparison and Intervention Group

	Comparison Group	Intervention Group	
Intervention	Explicit-Reflective NOS Instruction (Generic NOS Activities)	Explicit-Reflective NOS Instruction (Generic NOS Activities)	Metacognitive Strategies
	• Tricky track • Real Fossils- Real Science • The aging president • Young? Old? • That's part of life! • Black Box, The Tube, The Cube	• Tricky track • Real Fossils- Real Science • The aging president • Young? Old? • That's part of life! • Black Box, The Tube, The Cube	• Concept mapping • Researching the development of the ideas of peers • Writing two reflection papers about two NOS articles • Response to a case study

3.3.3.1. Explicit and Reflective Instruction in both Comparison and Intervention Group

In this study, the explicit-reflective NOS instruction, which is student-centered, and collaborative in nature (Lederman & Abd-El-Khalick, 1998), is used in both intervention and comparison groups to develop PSTs NOS understanding. This approach provides opportunities for reflective moments on PSTs NOS learning, so they involve them in activities that require designing lessons, alternative pedagogies, instructional units and assessment in context specific situations around NOS aspects

(Abd-El-Khalick, 2005). Moreover, the instructor asked questions or did hands-on activities which were designed to help students' to examine their NOS understandings. These NOS activities, whose descriptions were done by Lederman and Abd-El-Khalick (1998), were selected purposefully to be generic in nature rather than content-specific. Two of the activities addressed the function of, and relationship between, scientific theories and laws. Two other activities ("Tricky tracks" and "Real Fossils Real Science") addressed differences between observation and inference, and the empirical, creative, imaginative, and tentative nature of scientific knowledge. Three other activities ("The aging president", "That's part of life!", "Young? Old?") targeted the theory-ladenness and the social and cultural embeddedness of science. Finally, two black-box activities ("The tube" and "The cubes") were used to reinforce participants' understandings of the above NOS aspects. After the NOS related activities, students were directed to discuss their findings and ask questions. In each activity class discussions were provided by the instructor to explicitly involve the students in sharing their ideas about NOS. Moreover, the instructor engaged PSTs in reflective discussions about the importance of incorporating NOS aspects into their future classrooms and students' scientific literacy. These guided reflective discussions aimed PSTs give a motivation to reflect their ideas on ongoing NOS learning process more comfortably. On the other hand, only the students in the intervention group received training in metacognitive strategies during their engagement with thinking about NOS.

3.3.3.2. Training in and Use of Metacognitive Strategies in Intervention Group

In the intervention group, four metacognitive strategies were applied which were concept mapping (Novak, 1990; Novak & Gowin, 1984), researching the development of the ideas of peers (Oldfather, 2002), writing two reflection papers about two NOS articles and response to a case study (Thomas & Barksdale-Ladd, 2000). The intervention group had some training about metacognition and the logic behind it at the beginning of the semester. The instructor defined the term "metacognition", its components and benefits of thinking in a metacognitive manner for nearly two hours. It was aimed for PSTs to be aware of the aim while handling the metacognitive strategies. Therefore, they could examine the target NOS aspects more with their own understanding and also for teaching it in their future (Akerson & Abd-El-Khalick, 2009). PSTs spent time while constructing concept maps, asking questions to each other while discussing the ideas, writing their reflections about NOS articles and solving the case study. On the other hand, comparison group also handled the same NOS activities related to every aspect of NOS in each week. The comparison group's course hours were the same with intervention group, so comparison group PSTs were engaged for approximately the same amount of course hours as other NOS-related tasks embedded in the context of explicit reflective NOS instruction.

In addition, students were provided to reflect, both orally and in writing, on various NOS aspects during course readings, activities, and assignments. These opportunities aimed to help students articulate their acquired NOS understandings and apply them in various contexts. It was also aimed to help students to be involved and adopted to thinking metacognitively in every process they had.

In this study, one of the metacognitive strategies utilized to enhance PSTs' NOS aspects was concept mapping. Concept mapping is one of the most important metacognitive strategies. It is also a significant tool for PSTs to use in their future classrooms to provide meaningful learning (Heinze-Fry & Novak, 1990; Okebukola, 1990; Thomas & Barksdale-Ladd, 2000). After 4 weeks about NOS aspects handled, students' were expected to construct concept maps regarding science and NOS. For that reason, at the beginning of the semester PSTs were explained the key components of concept maps, including the meanings and usage of branches, linking words, cross links and concepts. Some sample concept maps were constructed regarding different topics in science lessons and then handled general discussions about the utility of concept maps. Therefore, it was aimed the students convey about the importance of concept maps on both teaching and learning.

After the examples of concept maps, students were asked "what is science?" and they were expected to map "science" in a concept map. They were wondered if they could relate NOS and its aspects with science directly. Students constructed their concept maps with their own science and NOS understandings. The instructor collected their concept maps and copied them. A month later, she distributed their concept maps to students for the second time to revise them according to their new knowledge about NOS. Therefore, it was aimed the students to make changes on them according to their increased NOS knowledge. This process repeated two times. Concept maps are powerful tolls to visualize the senses about the links between the topics, find the errors in it and correct them (Gallenstein, 2005). By the help of concept maps, students could monitor their own knowledge and control their thinking (McAleese, 1998). Throughout the concept mapping period, PSTs also used metacognitive strategies that they planned their own actions about where to place the right word, how to link it with others and reach the goal. They monitored their own decisions and after the concept maps distributed again, they found a chance to evaluate themselves and correct the errors. The aim of concept mapping is to increase metacognitive awareness. Therefore, the students were encouraged to think metacognitively, consider "science" and define it on a schema.

It was expected two gains from students' concept maps. First of all, PSTs' concept maps were expected to relate NOS targets and aspects with science and write words about them. Secondly, it was also expected to get an increase in the number of words and connections between the first and the second concept maps of the students. Some concept maps of the students appear in Appendix D.

Another metacognitive strategy which was utilized to enhance PSTs' NOS aspects was the researching the development of the ideas of peers. After the instructor distributed the concept maps to PSTs again, the students made changes on their own concept maps according to new NOS knowledge. Then, the instructor expected from students to exchange their concept maps with their friend. They were given fifteen minutes to analyze their friend's maps and prepare three questions about the changes made on it. Instructor provided examples of some possible questions such as “In your recent concept map, you added a crosslink between creativity and socially embeddedness? Why?” “What changed your ideas since you last built your concept map?” “Why did you clean some of the items about theory laden aspect of NOS?” Fifteen minutes later, the participants asked questions to each other about the reasons of their changes. From that end, it could be said that they provided each other to think about their own views of NOS.

The other metacognitive strategy was writing reflection papers. Two times throughout the semester, students were given ‘NOS related articles’ to which they were expected to write reflection papers about aspects of NOS by answering five metacognitive questions. Two of these questions were related with metacognitive are:

1. What are the ideas that challenge your previous views about NOS?
2. Did your views about a specific aspect of NOS change? Why?

Students were expected to reflect their ideas about the article in the light of these questions. As students had time to read NOS articles more deeply in the guidance of metacognitive questions, they were desired to think more about the questions and analyze the articles according to them. Major themes in reflection papers were shared and discussed in class provided by the instructor. Example reflection papers are given in Appendix E.

The last metacognitive strategy which was utilized to enhance PSTs’ NOS aspects was response to a case study. Case studies, which are carefully designed, provide students to improve their metacognitive thinking by reflecting on, synthesizing and applying their understanding of the subject, because they address specific questions or problems that are meaningful for students (Thomas & Barksdale- Ladd, 2000). Case studies provide PSTs to relate their teaching context with the case and take PSTs attention to the difficulties that students face while learning NOS aspects in class (Wahbeh, 2009). From that point of view, at the end of the semester, PSTs were given a case study which was about the differences between observation and inference. The Appendix C presents the case study used in this study. PSTs were divided into groups of 4-5. They were desired to discuss and write a plan of action to make accurate distinctions between these two terms. One groups' plan of action to the case study appear in Appendix F.

At the end of the semester, concept maps regarding NOS aspects, NOS related questions embedded in reflection papers and case study were also considered while analyzing post-test results of VNOS-C questionnaire. Therefore, the difference between intervention group and comparison group were identified with the comparison of their pre- test and post-test results by considering the students' efforts in these metacognitive strategies.

3.4. Instruments

3.4.1. The Nature of science questionnaire - Form C (VNOS-C)

There are several versions of the Views of Nature of Science Questionnaire developed by Lederman, Abd-El-Khalick, Bell, and Schwartz (2002), but VNOS–B (7 items) and the VNOS–C (10 items) are the most frequently used ones. All of the questions in VNOS-C questionnaire were open-ended. The VNOS-C version was chosen for this study which is a modified and expanded version of the VNOS-B. It is important to focus on that the aspects on this VNOS-C questionnaire are interrelated. The aspects of NOS addressed by the VNOS-C include seven target aspects which are scientific knowledge is tentative (subject to change), empirically based (based on and/or derived from observations of the natural world), subjective (theory-laden), partly based on human inference, require imagination, and creativity, and that it is also socially and culturally embedded, difference between observation and inference, and the function of and relationship between scientific theories and laws.

As it is mentioned, the VNOS-C requires ten opened-ended questions which are harder to score and more difficult to interpret than forced-choice questions. For that reason, the VNOS-C responses were coded by the researcher and another researcher who has a master degree on elementary science education independently, and codes were validated through extensive discussions with the researcher and advisor, who has experience with qualitative research related to the nature of science. Therefore, it was aimed to establish interrater reliability of the VNOS-C. Lederman et al. (2002) suggested respondents should be asked to explain their responses, to make clear the meanings they ascribe to key terms by semi-structured interview. In order to examine the change of the pre-service science teachers' understanding of NOS during the intervention, this questionnaire was administered to both intervention and comparison groups at the beginning and at the end of the semester. Validity of the VNOS-C questionnaire was affirmed by interviewing the participants using the semi-structured interview with a random sample of 30% that their responses were compared to written responses to the VNOS-C questionnaire for consistency. When there existed inconsistencies between participants' interview and questionnaire responses, interpretations of written responses were modified based on explanations during the interview (Lederman et al., 2002).

3.4.2. Metacognitive awareness inventory (MAI)

Metacognitive Awareness Inventory (MAI) was developed by Schraw and Dennison (1994), translated and adapted into Turkish by Sungur and Senler (2009). It is a 52-item 5 points Likert-type scale ranging from "always" to "never" and measures two aspects of metacognitive awareness: knowledge of cognition (KoC), and regulation of cognition (RoC). This two-component model is consistent with theoretical expectations (Flavell, 1987; Israel et al., 2005) and has a strong empirical support. Schraw and Dennison reported that the factors associated with the two components were highly reliable ($\alpha = .90$) and intercorrelated ($r = .54$). The internal consistency for the KoC and RoC components was high, and ranged from .93 to .88. The knowledge of cognition (KOC) scale comprises 25 items and has three subscales: declarative knowledge, procedural knowledge, and conditional knowledge.Declarative knowledge is the knowledge about learning and one's cognitive skills and abilities. Procedural knowledge is the knowledge about how to use strategies and conditional knowledge is the knowledge about when and why to use strategies (Schraw & Dennison, 1994, p. 471). The regulation of cognition (RoC) scale comprises 27 items and consists of five subscales: planning, organizing and information management, monitoring, debugging, and evaluation. Planning requires planning, goal setting, and allocating resources. Organizing is the implementation of strategies and heuristics that help the person to manage information. Information management includes organizing, elaborating, summarizing, and selectively focusing on important information. Monitoring is the on-line assessment of one's learning or strategy use. Debugging requires the strategies used to correct performance errors or assumptions about the task or strategy use. Finally, evaluation is the post-hoc analysis of performance and strategy effectiveness (Schraw & Dennison, 1994).

MAI totally includes fifty-two questions which aim to measure the metacognitive awareness of the students. The students were expected to select an item for each question ranges always agree- always to disagree. MAI were applied to both intervention and comparison group, both at the beginning and at the end of the semester.

3.5. Data Analysis

All of the data were analyzed at the end of the course in order to avoid some prejudgments, which would affect the study. The VNOS-C and MAI questionnaire and interviews, reflection papers, responses to case study and concept maps were analyzed.

3.5.1. Analysis of VNOS-C Data

The total pre-test and post-test scores of the VNOS-C responses were analyzed to determine profiles of each participant's views of the seven aspects of NOS.

All statements relevant to a certain NOS aspect across the questionnaire were holistically examined—related aspects and relations between aspects were taken into consideration—in order to categorize the participant's views as naïve, partially informed or informed. The analysis of VNOS-C responses was devised in three stages. In the first step, the unit of analysis was determined. The unit of analysis require a paragraph, group of sentences, sentence or phrase that contained a single unambiguous theme about the nature of science defined (Palmquist & Finley, 1997, p. 600). Therefore, I assigned codes to every aspect of NOS according to Lederman et al. (2002) and Hanuscin and Lee (2009) that shows which words or phrases expresses naïve, partially informed or informed view of NOS. For instance, in tentativeness aspect, "No change", "changes because everything changes", "Change due to just technology developments" kinds of explanations shows naïve view. "...Discovery of new knowledge", "… that is new knowledge about previous knowledge", "…Development of old knowledge" expressions show partially informed view. "Knowledge change due to reinterpretation of old knowledge, accepting of shifts", "…Theories provide a framework for current knowledge and future investigation" kinds of explanations showed informed view of NOS. The codes of aspects were dynamic that they were modified when new themes and ideas emerged.

In second step of analysis, it was constructed a chart including both pre and post-tests of PSTs. It was written every important and indicator answer of PSTs in each aspect, that provide to determine the type of view. Then, the answers in the chart were compared and contrasted with codes and they were categorized in every aspect with naïve as 1, partially informed as 2 and informed as 3. Pre-tests of PSTs were categorized firstly, in order to avoid prejudgments and the same categorization method was applied in analyzing post-tests of PSTs.

In final step, at the end of the categorization, each student had a point as 1 (naïve), 2 (partially informed) or 3 (informed) in every aspect of both pre and post - tests. For each student, the scores were analyzed and searched about the numbers of naïve, partially informed and informed views. From this perspective, it was given a total score to each student's pre-tests and post-tests. In this process, while giving the PSTs a total score for their pre-test and post-tests, especially for the students who has one naïve score, three partially informed scores and three informed scores, their interview answers, their concept maps and reflection papers were considered. It was expected from this analysis to show if the interpretations of the responses and the answers of the interviews were parallel to each other or not (Lederman et al., 2002). At the end, after this comparison and analysis, each student had a pre-test score and a post-test score. From these scores, it was calculated the percentage of how many PSTs increased his total score from 1 to 2, 2 to 3 or 1 to 3.

3.5.2. Analysis of Metacognitive Awareness Inventory (MAI) Data

After the data collected from all participants, they were analyzed by using Statistical Package for the Social Sciences program (SPSS) 15.0. In order to analyze MAI scores, descriptive statistics were done.

The total pre-test and post-test scores of MAI (KoC and RoC scores) were analyzed by summing participants' item ratings. Raw scores were shown as percentages to make interpretation easier. Gain scores for KoC and RoC were analyzed by subtracting the pre-test scores from the post-test scores. After that; analyses of variance (ANOVA) on the gain scores of intervention group were used as the independent variable. Then it was decided according to the treatment's main effect if there was a significant increase or not (Cook & Campbell, 1979; Shadish et al., 2002).

3.6. Validity and Reliability

In all research studies, there are some considerations that may affect the usefulness of the study. First of all, in order to prevent internal validity threats like location, subject attitude instrumentation, and implementation, the conditions which the study held were standardized that all participants filled instrument in their own classes and all data were collected by researcher. Participants' responses to the VNOS-C were coded by the researcher herself and another researcher, who has a master degree on elementary science education independently in order to minimize the effect of researcher bias. Then, assigning codes were validated through extensive discussions with the advisor, who has experience with qualitative research related to the nature of science.

Alpha coefficient was calculated for all of the quantitative instruments for reliability. The reliability values of MAI for the factors were .89 for Pre KoC, .91 for Pre RoC, .89 for KoC, .91 for Post RoC. Moreover, the method of the study which requires the design of the study, the procedures, data collection and analysis process, and the participants and the determination of these participants were clearly described.

3.7. Limitations of the Study

This study has some limitations. In this study, the selected sample size is limited to 33 because of the accessibility; therefore, the results of the study can be generalized only to all pre-service science teachers who received explicit reflective NOS instruction in Ankara. Completion time of the VNOS-C took about forty-five minutes, so that may have caused boredom and tiredness for some PSTs. Moreover, the background of participants, their worldviews, languages and their cultures are related to their NOS views (Liu & Lederman, 2007). As the study was conducted in

Ankara and the participants are Turkish PSTs, their cultural and religious characteristics might affect the results of the study.

CHAPTER IV

RESULTS

The study aimed to assess the effect, if any, of using metacognitive strategies embedded in explicit–reflective NOS instruction on the development of pre-service science teachers' understandings of NOS. This chapter includes the results generated from data analysis. In this part, all of the data are analyzed and summarized.

4.1. Pre-service Science Teachers' NOS Understandings

In this section, firstly pre-service science teachers' pre-intervention NOS understandings were described. Then, the pre-service science teachers' post-intervention NOS understandings were examined with changes in individual PSTs understanding.

As it was mentioned in the method section, 33 PSTs completed both the pre-tests and post-tests of VNOS-C questionnaire. In addition, it was interviewed four randomly selected PSTs from both intervention and comparison groups, after the implementation of both pre-tests, and post-tests of VNOS-C questionnaire. The semi-structured interviews helped to understand the PSTs views better by comparing their expressions with their responses in their questionnaire. That also served to support the validity of the questionnaire.

Results are given in three sections, namely PSTs' pre-intervention NOS understandings, PSTs' post-intervention NOS understandings and the comparison of pre and post-intervention NOS understandings. A number, ranging from one to eighteen, was assigned to each PST. Then, PSTs were identified with codes comprising letters and numbers. 'I' and 'C' refer to the intervention and comparison groups respectively; the letters B (i.e., before), A (i.e., after) were assigned to indicate whether the particular profile is a pre or post VNOS-C profile respectively. For instance, 9B-I indicates a quote taken from participant 9 from intervention group pre-VNOS-C profile.

4.1.1. Pre-service Science Teachers' Pre-intervention NOS Understandings

Pre-test of VNOS-C questionnaire was applied at the beginning of the semester. The comparison group consisted of 18 PSTs; intervention group consisted of 15 PSTs. The results and related interviews showed that the greater majority of PSTs in both groups held overall naïve views of targeted NOS aspects. In comparison group only two of the PSTs (11.1%) held partially informed views of NOS. However, all of the PSTs in intervention group held naïve view of NOS.

The pre-test and post-test results of intervention group and comparison group are analyzed respectively below.

4.1.1.1. The Empirical NOS

Results showed that PSTs in comparison group, 78% (14) held naïve, 17 % (3) held partially informed and 5 % (1) informed views on the empirical NOS; in intervention group 87% (13) held naïve, 13 % (2) held partially informed and nobody held informed views on the empirical NOS aspect. PSTs who showed naïve views on the empirical NOS aspect thought science studies everything and they were less able to understand the difference between science and other disciplines as shown in following quotes:

> I think science is technology and this is the main difference between scientific discipline and other disciplines. If technology improves, science also improves. (9B-I)

> Science requires a research process. Science is more accurate than other disciplines. Experiment is a must to make the scientific knowledge universal. (9B-C)
>
> Science explains everything … eases the life … it is reality. (1B-C)

There were a few PSTs who had partially informed views indicated science is a process requiring making experiments, observations and data collection as evident in the following quotes:

> In scientific investigations, observations, experiments and evidences are required. (2B -C)
>
> Science is a bunch of knowledge which tries to explain natural phenomena via observations and experiments. (4B-C)
>
> Science depends on observations. Science observes developing events, draw conclusions and emerge new concepts. Everything in our life is the base of scientific results. (7-B-I)

However, in order to be categorized as informed, participants expected to write that science requires exploring nature, coming up conclusions about how and why things work. Science is a brunch of theoretical ideas that can be tested by observation, doing experiments and thinking. Therefore, only one participant in comparison group held informed view of NOS. He said: "I think science is an inquiry of nature using scientific methods like observation, experiment, hypothesis and conclusion. Experiment is…science related matters to give a conclusive result. … [Via experiments] scientists build a new set of theories which are necessary for a new set of scientific knowledge. [Further explanation]"(17-B-C).

4.1.1.2. The Inferential NOS

Participants' responses in comparison group regarding the inferential NOS werecategorized as either naïve (88.9%), partially informed (11.1%) and informed (0) views; in intervention group, however, all of the PSTs held naïve (100 %) views of NOS (see Table 4.1).

The participants' answers which had no implication of emphasis for inference based on observation or experiment were considered as naïve views of NOS. They thought scientists only guess while reaching the scientific facts. Following quotes are the examples of their views:

> They did a lot of experiments about nucleus. According to their experiment results, they proved it. (10B-C)
>
> The scientists seem to be considerably certain about the structure of the atom. (6 B-I)

Most of the participants had no explanations on related questions about inferential aspect of NOS. Therefore, most of the participants held naïve view. Only two PSTs, who were in comparison group, held partially informed views that they claimed scientists don't see directly and they make predictions. The following shows these two participants' views:

> Well, scientists are not certain about the atomic composition. The fact is that several experiments carried out and different models were developed to explain…the data have been interpreted in different ways. [Implication for inference] (17B-C)
>
> …as a result of continuing predictions and investigations scientists introduced new theories on existing ones. … [Some] atomic particles are retained by sending light beams and tracing the way that they follow. [~implication for inference/interpretation] (13B-C)

In order to be categorized as informed, PSTs were expected in their responses to indicate for observation and inference and also making predictions based on data and patterns. There were no PSTs who were informed views of inferential aspect of NOS.

4.1.1.3. The Theory-Laden NOS

Participants' responses in comparison group regarding the theory laden NOS were distributed as naïve (66.7%), partially informed (33.3%) and informed (0) views of NOS. In intervention group, 73.3% of PST held naïve views and 26.7% of PST's partially informed views of NOS (see Table 4.1).

The participants who were categorized as naïve indicated that observations are neutral, or scientific facts are the "truth" so, personal ideas, beliefs or background do not affect them. Following quotes illustrates participants' views as examples:

> These differences are because of that hypothesis cannot be proven. So everybody can say something about it. (15B-C)
>
> ...science does not change from person to person. It is not an opinion or consideration. (12B-I)

The PSTs who were considered as partially informed views of NOS, has recognition of subjectivity and they believe background may lead to different explanations. However, informed views were expected to indicate different people whose background, beliefs and ideas are different may have different explanations from the same data. It was important to mention if there is an indication of more detailed explanation of subjectivity that how it frames scientists thinking and how their study, thinking affect their work. There were no informed view of NOS in both comparison and intervention group. Some examples from PSTs' who held partially informed view of NOS are as follows:

Scientists use the same data and make different hypothesis. This is derived from different inferences and thinking styles. (7B-I)

…I guess that's why they had different ideas why dinosaurs become extinct they looked at the different time periods or maybe interested in different way. (7B-C)

Yes, there is the same set of data in front of scientists. However, back or old knowledge of scientists are very different from each other. Due to this differentiation, there are two different conclusions from the same set of data. (12B-C)

4.1.1.4. The Tentative NOS

Participants' responses in comparison group regarding the tentative NOS were distributed as naïve (94.4%), partially informed (5.6%) and informed (0) views of NOS. In intervention group, 80% of PSTs held naïve view and 20% of PSTs partially informed view of NOS (see Table 4.1). There were no PSTs who held informed views of NOS in both groups.

Participants who held naïve views of NOS indicated that scientific knowledge changes like everything in the world, because there is an accumulation of knowledge. Moreover, they believed that change occurs just due to technological developments. Examples are shown in following quotes:

I believe that scientific theories do change, the conditions of the era let us see something different from the past. (3B-C)

Science is both universal and personal. Also, science can be changed by different points of views. However, in physics, chemist, biology and astronomy scientific knowledge is definite. (1B-I)

Theories can change by the help of technological developments. Technology help scientists to realize what they haven't realize before. (13B-I)

Participants who held partially informed view about tentative aspect of NOS indicated that scientific knowledge changes due to the development of old knowledge and discovery of new knowledge. Examples of their views are as follows:

> Theories can change, because further experiments about the same topic may invalidate the current theory. Different experiments with different views and approaches can develop the theories by eliminating the shortcomings. (11B-I)
> People cannot reach the whole knowledge at any time that as the mankind survive scientific knowledge will change. As scientific knowledge can change, all knowledge can change, too...as technology and thoughts of people change, theories also change. (2B-I)

There were no PSTs to be categorized as informed view about the tentativeness aspect of NOS that participants' were expected to indicate; scientific knowledge changes in light of new evidence, technological advances, and most importantly, in light of new theoretical ideas (Abd-El-Khalick, 1998). PSTs expected in their responses to write knowledge change due to reinterpretation of old knowledge, accepting of shifts or theories provide a framework for current knowledge and future investigations.

4.1.1.5. Nature of Scientific Theories and Laws

All of the participants (100%) both in comparison and intervention group held naïve views in their pre responses about the nature of scientific theories and laws. Their shared idea was laws do not change. They indicated there is a hierarchical relationship between theories and laws that theories become laws after they are proven. The examples of their views are as follows:

> A theory is required to be proven in order to become a law. (1B-C)

> Theory can be changed after an exception is found. But law cannot be changed. (3B-C)
>
> Scientific theory is a statement or model that is used to explain some phenomena. A theory can be modified or simply turn out to be wrong. On the other hand, a scientific law applies to all cases and it is not changed. (6B-I)
>
> Theory can be proved by experiments and observations. However, laws must be accepted by scientists. (15B-I)

Most of the participants both in comparison and intervention group, expressed their ideas in the same way and with the same logic. The PSTs who were interviewed also claimed that they were taught theories became laws when they were proven and laws are stronger than theories. Therefore, all of the participants hold naïve view of this aspect of NOS.

4.1.1.6. The Creative NOS

Pre VNOS-C responses of PST's showed in comparison group that 44.4% of the participants held naïve views of the creative NOS, while 33.3% indicated partially informed views on this aspect. In intervention group, 53.3% of the participants held naïve views of the creative NOS, while 47.7% indicated partially informed views on this aspect. There were no participants with informed view of creative NOS.

Participants who held naïve view indicated that scientific knowledge does not require creativity and imagination and creativity is not a part of scientists' work. Also, they expressed that scientists use their creativity in only some parts of their experiments and it is not possible to use imagination and creativity in all stages of their work. Participants quotes are as follows:

> They can't use imagination, because they should show the facts to people to prove and imagination cannot be showed. (15B-C)

Scientists develop their hypothesis according to their guesses in the planning stage of their investigations. (1B-C)

…there are thousands of evolutionary theories, but each one is accepted only by their theorists. (7B-I)

However, PST's to be categorized as partially informed view they need to indicate that scientists use of imagination and creativity in some cases or at some parts of their investigation or they use it. PSTs quotes are as follows:

…without imagination there wouldn't be any discoveries or inventions. Scientists use their imagination before planning, design and data collection. (9B-C)

Yes, I think they use creativity and imagination during planning and design. …they have some sorts of expectations (hypothesizes) and this expectations are drawn through careful imagination and creativity. (17B-C)

Science is a discipline of having its own rules, imagination and creativity is not always possible. The best scientists are the ones who can do this...diagnosing an illness that never succeeded by others, finding a cure to an illness require creativity. It requires combining their knowledge of science with their imagination and creativity. (9B-I)

PSTs were expected in their responses to write the use of imagination and creativity in every part of investigation to create explanations and come up conclusions. However, there were no PSTs with informed view of creative NOS.

4.1.1.7. Social and Cultural Embeddedness of Science

PSTs pre VNOS-C responses showed that 72.2% of the participants held naïve views, 27.8% showed partially informed views on the social and cultural embeddedness of science in comparison group. On the other hand, in intervention group, 80% of the participants held naïve views, 20% showed partially informed views on this aspect of NOS.

Most of the participants who held naïve view agreed that science is universal and scientific knowledge is not affected by society, also scientific knowledge does not affect society. PST's quotes are given as following:

> Science is universal. Mendel's law is not just for our culture or social values. (3B-C)
>
> Science is universal. Science cannot reflect a nation's social, political and cultural values; it [science] goes beyond the society. (9B-C)
>
> Science is universal. ...knowledge is examined in the same way all over the world. (13B-I)
>
> Science is universal; it doesn't reflect cultural values, because Newton's laws are true in every place of the world. (10B-I)

On the other hand, informed view of NOS requires the expression that scientific knowledge affects and is affected by the social and cultural, economical, religious...etc. factors of scientists (Abd-El-Khalick, 1998). Only one of the participants gave an example that shows these relationships. For instance "Culture has an enormous effect on science. For example in ancient Egypt, mummification of pharaohs had led to emerge and development of medicine." (1B-C). PSTs who were categorized as partially informed views mentioned in their responses that society/culture as an influence on science or vice versa, but they do not have enough explanations and examples.

PSTs who had partially informed views indicated as follows:

> Science is closely related with cultural and social values. They are always in interaction. (16B-C).
>
> Science is derived from needs of a society. Society's needs change according to time and place that lead people to do research. (5B-I).

4.1.2. Pre-service Science Teachers' Post-Intervention NOS understandings

The results of post-test responses of VNOS-C questionnaire are presented in Table 4.1 and Table 4.2. The post-tests results showed that the greater majority of pre-service science teachers in both groups increased their knowledge from naïve to partially informed or informed; partially informed to informed views of targeted NOS aspects. In comparison group, 88.9% of naïve views of general profile in pre-test responses decreased to 11.1% in post- responses, partially informed views increased from 11.1% to 61.1% and informed views of NOS increased from 0% to 27.8%. In intervention group, all of the PSTs held naïve views of NOS. The results of post-tests showed naïve views of general profiles decreased from 100% to 6.7%; partially informed views of general NOS profiles increased to 40% and informed views of general NOS profiles increased to 53.3%.

According to post-test results of PSTs, the changes in all seven aspects are presented below.

4.1.2.1. The Empirical NOS

Results of the post-tests showed the desirable change both in comparison and intervention group. The number of PSTs in comparison group who held naïve view of NOS decreased from 14 (77.8%) to 3 (16.7%); partially informed views of NOS increased from 3 (16.7%) to 11 (61.1%), informed view of NOS increased from 1(5.6%) to 3 (22.2%). On the other hand, in intervention group naïve view of PSTs decreased from 13(86.7%) to 1(6.7%), partially informed views of NOS increased from 2 (13.3%) to 7 (46.7%) and informed views of NOS increased to 7 (46.7%). The PSTs especially used the word "empirical" and defined science as experimental depending on observations and inferences in their responses to express the difference between science and other disciplines. As an example, two of the participant's responses who developed their knowledge to informed view indicated their ideas as follows:

> ...Scientific knowledge is not developed only the way of experiments. Some are developed by only observation, even by inferences and/or predictions. Scientific knowledge provides explanations and solutions to some of the natural phenomena... [supported by examples] (17A-C)
> The content of science is determined (based) by observations and empirical data...it bases on its inferences about natural phenomena in observation...In science we use experiments, models so that we can proof in a way the knowledge. [Experiments and observations] help us in making some inferences...Sometimes it is not possible to do experiments, in the space for example. As long as you interpret your data…in a logical way, it tells you… [about natural phenomena] (Interview follow-up) (6A-I)

4.1.2.2. The Inferential NOS

By the decrease of 72.2%; PSTs in comparison group who had naïve views of inferential NOS became 3 (16.7%); by the increase of 50% partially informed views of inferential NOS became 11 (61.1%) and by the increase of 22.2% informed view of NOS became 4 (22.2%). All PSTs in intervention group who had naïve views of inferential NOS at the beginning, decreased by 93.3% and only one participant continued to have naïve conceptions about this aspect. 7 PSTs (46.7%) became partially informed and 7 PSTs (46.7%) became informed views of inferential NOS aspect.

A total of 4 PST’s from comparison group and 7 PST’s from intervention group held informed view of NOS. They expressed their views about inferential aspect of NOS by connecting the creativity of scientists to their observations and inferences. Some examples are as follows:

> Scientists can't observe every single data but they can infer and create a model for their explanation and there is no 100% certainty about a phenomenon in science. [Further explanations and example – Rutherford model] (12A-C)
>
> Generating scientific knowledge requires/involves human inference. They benefit from their observations and recorded data. Their atom models are not the copies of reality. They construct scientific knowledge by using their creativity [implication for prediction] (9A-I)

On the other hand, some participants holding such views were categorized as partially informed views on the inferential NOS that "Scientists don't see atoms directly. Based on their creativity, they form a model in their minds according to observation and collected data" (4A-C). "Every knowledge can not require experiments, so scientists make inference and prediction" (1A-I)

4.1.2.3. Theory-Laden NOS

The post-test results of theory laden aspect of NOS showed the sharp change in both groups especially in intervention group. The number of PSTs in comparison group who held naïve views of NOS decreased from 12 (66.7%) to 2 (11.1%); partially informed views of NOS increased from 6 (33.3%) to 8 (44.4%), informed views of NOS increased to 8 (44.4%). On the other hand, in intervention group naïve views of PSTs decreased from 11 (73.3%) to 1 (6.7%), partially informed views of NOS decreased from 4 (26.7%) to 2 (13.3%) and informed views of NOS increased to 12 (80%).

There was a general belief and idea in PSTs views that scientists' background, beliefs, previous knowledge and culture affect their work. They expressed their ideas in a view that any work is apart from human effect. As an example, three of the participant's responses who developed their knowledge to informed view indicated their ideas as follows:

It is like to look at the same picture, but to see different things. Scientists may interpret the same data differently based on their study area, training, beliefs, previous knowledge, and culture. (8A-C)

Scientists are different persons that have different backgrounds, beliefs, social and cultural structures, expectations and preconceptions; even in observations of scientists there is subjectivity...of course scientists end up with different conclusions even though they look at the same evidences. (12A-C)

Scientific knowledge is subjective. Every scientist have different point of view due to their different previous knowledge, belief, experience and expectations so that they reach different conclusions otherwise they all reach same conclusion and in that case scientific knowledge would not be improved. (3A-I)

4.1.2.4. The Tentative NOS

By the decrease of 66.6%; PSTs in comparison group who had naïve views of inferential NOS became 5 (27.8%); by the increase of 55.5% partially informed views of inferential NOS became 10 (55.6%) and by the increase of 11.1% informed views of NOS became 4 (11.1%). PSTs in intervention group who had naïve views of tentative NOS at the beginning, decreased by 66.7% and only two PSTs continued to have naïve conceptions about this aspect. By the increase of 33.3%, partially informed views of tentative NOS became 8 (53.3%) and by the increase of 33.3%, informed views of tentative NOS became 5 (33.3%) became informed views of inferential NOS aspect.

Post- test results showed that tentativeness aspect of NOS was one of the highest percentages of the results that stay naïve among other aspects. The general idea among PSTs was, as technology develops and time passes, everything changes. “According to technological developments and equipment, theories change and scientists make new experiments.” (4A-C)

The PSTs who held partially informed views of NOS expressed their ideas that:

> "Scientific theories change because scientific knowledge is changeable. When some new observations are made or some new evidences are found about a scientific knowledge, theories can change." (16 A- C)
> There became a change in PSTs' ideas and they held informed views that "In scientific knowledge tentativeness is not avoidable...every scientist can come up with different explanations for phenomena and new evidence or even new interpretations with same evidence can lead to change in scientific theories. (12 A- C).

Reinterpretation, change and/or develop of old knowledge lead to change of scientific knowledge. These were the key words that participants used in order to express their views:

> Scientific knowledge is tentative and subject to change...Theories can change because they have parts of human imagination or inference for that reason they can be change in the light of new evidences. If we do not learn these theories or law how can we understand their drawbacks? In order to enhance or support a theory we need to investigate it deeply and comprehend what it really says. (3A-I)

4.1.2.5. The Nature of Theories and Laws

As the pre-test results showed, all of the PSTs held naïve views of the nature of scientific theories and laws aspect of NOS. However, in post-test result of participants, there is a sharp change in both groups especially in intervention group. The number of PST's in comparison group who held naïve view of NOS decreased to 3 (16.7%); partially informed views of NOS increased to 6 (33.3%), informed views of NOS increased to 9 (50.0%). On the other hand, in intervention group naïve views of PST's decreased to 1 (6.7%), partially informed views of NOS increased to 3 (20.0%) and informed views of NOS increased to 11 (73.3%).

The participant whose views changed to partially informed view expressed their ideas as follows:

> ...scientific theory and scientific laws are different. Theory explains the events, how a scientific phenomenon occurs while law shows the relationships between observable phenomena. (5A-C)
>
> Scientific theory gives explanations about how a phenomena works, but scientific law explains relationships in those phenomena. [Ex: Mendel's law versus chromosome theory] (8A-I)

The students whose views changed to informed views of NOS in their post-tests showed that they explained their ideas in detail; they could differentiate the meanings of theory and law, and understand there is no hierarchical order between them. The PSTs example answers are as follows:

> ...theory explains the basic principles of a phenomenon and describes it, law draws relationships about this phenomena. [Ex: kinetic molecular theory vs. Boyle's law]. At the beginning of the semester I was thinking that theories become laws as they develop. Now I think that there is no such a hierarchy (Interview follow-up). (7A-C)
>
> Law is a different kind of knowledge. There is no a hierarchy for their accuracy (Interview follow-up). A scientific theory is the kind of scientific knowledge that explains how some phenomena occurs. A scientific law is the kind of scientific knowledge that gives relations between phenomena in nature. [The big bang theory and the laws of motion] (6A-I)

4.1.2.6. The Creative NOS

The least number of PSTs who held naïve views in pre-tests were in creative aspect of NOS. By the decrease of 33.3%; only two participants continued to have naïve conceptions about this aspect. PSTs in comparison group who had naïve views of creative NOS became 2 (11.1%); by the decrease of 22.3% partially informed views of inferential NOS became 6 (33.3%) and by the increase of 55.6% informed views of NOS became 10 (55.6%). PSTs in intervention group who had naïve views of tentative NOS at the beginning, decreased by 53.3% and there were no naïve views of that aspect exist. By the decrease of 14.4%, partially informed views of tentative NOS became 5 (33.3%) and by the increase of 66.7%, informed views of tentative NOS became 10 (66.7%) became informed views of creative NOS aspect.

Two PSTs in comparison group had no accurate explanations, so they were categorized as naïve views of NOS. However, there were no participants in both groups who claimed that "creativity is used only in some parts of investigations, for instance in planning or data collection part." Nearly all of them expressed that scientists use their creativity and imagination which provide them to wonder, to interpret and to explore the scientific knowledge. Moreover, the PSTs who hold informed views of creative NOS mentioned that scientists use their imaginations in all steps of investigation. "How they plan or design an experiment or a study, how they can collect data or where they can get the data and also while interpreting this data they use their imagination and creativity. [Ex: Dinasour bones]"(14A-I).

> Creativity is needed and can be used in all steps of a study. They [scientists] imagine when they don't have a chance to do experiments or for old events. Scientist may reach genuine results when they don't follow the common-known scientific method. (Interview follow-up) (1A-I).
>
> Scientists use their creativity and imagination during their study since they don't have the chance to observe every detail at this point ...they are generally

data based and not copies of reality [Further explanation and example]. (12A-C)

4.1.2.7. Social and Cultural Embeddedness of Science

The post-test results of social and cultural embeddedness of science aspect of NOS showed a sharp change in both groups especially in intervention group. The number of PSTs in comparison group who held naïve views of NOS decreased from 13 (72.2%) to 4 (22.2%); partially informed views of NOS increased from 5 (27.8%) to 10 (55.6%), informed views of NOS increased to 4 (22.2%). On the other hand, in intervention group naïve view of PST's decreased from 12 (80.0%) to 3 (20.0%), partially informed views of NOS increased from 3 (20.0%) to 7 (46.7%) and informed views of NOS increased to 5 (33.3%).

The post-test results showed that 4 from comparison, 3 from intervention group, 7 participants still held naïve views of social and cultural embeddedness of NOS.PSTs continued to claim that "Science is not affected by social and cultural values, because science is a cut above society"(3A-C). "Science is universal, because all scientists are in communication in the world. However, for some countries culture can affect the scientific knowledge" (13A-I).

On the other hand, most of the participants' views changed in a positive way that they expressed scientific knowledge affect and was affected from social and cultural values of people. Some expressions are as follows:

> Scientific knowledge is socially and culturally embedded, because it is human product, so it is inevitable not to be influenced by society and culture. The values and expectations of culture determine what and how science is conducted, interpreted and accepted. (13 A- C)
>
> Science reflects social and cultural values. For example some application in science can be supported in one country and others can reject it. Scientific applications, experiments also improvements are affected by socio-cultural

structure of society. And science is not universal. For instance in medicine application of embryonic stem is used but in some countries it is not allowed. It is regarded as unethical. (3A- I)

To sum up, except social and cultural influence aspect of NOS, PSTs in intervention group showed a substantial growth. While the responses of comparison and intervention group participants' compared, this great change could be seen.

4.1.3. The Comparison of Pre and Post-Intervention NOS Understandings

Table 4.1 shows PSTs views on each NOS aspect before and after the intervention with the results of pre and post-tests. Table 2 shows the percentage gains in PSTs NOS understandings in comparison and intervention groups.

Table 4.1. Pre-test and Post-test views of the target aspects of the NOS for participants in the comparison and intervention groups

NOS Aspect	Comparison Group						Intervention Group					
	Naïve		Partially informed		Informed		Naïve		Partially informed		Informed	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Empirical	77.8	16.7	16.7	61.1	5.6	22.2	86.7	6.7	13.3	46.7	0	46.7
Tentative	94.4	27.8	5.6	61.1	0	11.1	80	13.3	20	53.3	0	33.3
Theory laden	66.7	11.1	33.3	44.4	0	44.4	73.3	6.7	26.7	13.3	0	80
Inferential	88.9	16.7	11.1	61.1	0	22.2	100	6.7	0	46.7	0	46.7
Creative	44.4	11.1	55.6	33.3	0	55.6	53.3	0	47.7	33.3	0	66.7
Theory vs. law	100	16.7	0	33.3	0	50	100	6.7	0	20	0	73.3
Soc& Cul influence	72.2	22.2	27.8	55.6	0	22.2	80	20	20	46.7	0	33.3
General Profile	88.9	11.1	11.1	61.1	0	27.8	100	6.7	0	40	0	53.3

All data are percentages.

Table 4.2. Percentage change in participants views of the target aspects of NOS

NOS Aspect	Comparison Group			Intervention Group		
	Naïve	Partially informed	Informed	Naïve	Partially informed	Informed
Empirical	- 61.1	+44.4	+16.6	-80	+33.4	+46.7
Tentative	-66.6	+55.5	+11.1	-66.7	+33.3	+33.3
Theory laden	-55.6	-11.1	+44.4	-66.6	-13.4	+80
Inferential	-72.2	+50	+22.2	-93.3	+46.7	+46.7
Creative	-33.3	-22.3	+55.6	-53.3	-14.4	+66.7
Theory vs. law	-83.3	+33.3	+50	-93.3	+20	+73.3
Soc& cul influence	-50	+27.8	+22.2	-60	+26.7	+33.3
General Profile	-77.8	+50	+27.8	-93.3	+40	+53.3

Table 4.3. Chi- square test of independence for distribution of pre-test and post-test NOS understandings (N= 33)

	Pre-test (Intervention vs. comparison)			Post-test (Intervention vs. comparison)		
NOS aspect	X^2	d*f*	p	X^2	d*f*	p
Empirical	.972	2	.615	2.455	2	.293
Tentative	1.603	1	.206	2.795	2	.247
Theory laden	.172	1	.678	4.498	2	.106
Inferential	1.774	1	.183	2.455	2	.293
Creative	.259	1	.611	1.833	2	.400
Theory vs. law				1.943	2	.378
Social & Cultural influences	.270	1	.604	.515	2	.773

Table 4.3 presents the results of a chi-square test for independence of the distribution of the comparison and intervention group participants' naïve, partially informed, and informed views of NOS at the at the beginning and at the end of the study. The results showed that at the beginning of the study, PSTs' views of all seven NOS aspects were not significantly different (p > .05). However, the chi-square test indicates that the intervention group post-test views of the all seven aspects of NOS were also not significantly higher (p > .05) than those of participants in the comparison group. However, the post-test results showed a great increase in intervention group in the post-test views of empirical, tentative, theory laden, inferential, creative and theory vs. law, social and cultural influence aspects of NOS.

Only the social and cultural influence aspect of NOS did not show a big difference between participants in the comparison and intervention groups.

4.2. Participants' Views of Metacognitive Awareness

Table 4.4 shows comparison and intervention group PSTs both pre-test and post-test mean KoC and RoC scores and mean percentage gains from the pre-test to the post-test scores for KoC and RoC scores. It was important to find metacognitive awareness level at the beginning of the study. Therefore, it was assumed that comparison and intervention groups were at the same metacognitive awareness level at the beginning of the study.

Table 4.4. KoC and RoC means and mean gain scores for the intervention and comparison group

		Comparison Group (n=18)			Intervention Group (n= 15)		
MAI	Statistic	Pre-test	Post-test	Gain[a]	Pre-test	Post-test	Gain[a]
KoC	M	79.22	79.87	0.65	67.45	79.29	11.84
	SD	7.07	10.28	7.53	10.88	6.45	9.19
RoC	M	75.24	77.59	2.35	65.79	77.18	11.39
	SD	6.85	9.85	7.70	9.49	5.90	8.95

All MAI scores are presented as percentages for ease of interpretation. aGain = *M*post-test –*M*pre-test.

Independent sample t-test was conducted to compare differences from pre-test means to post-test means. However, significant differences were found within the comparison group and intervention groups' KoC and RoC pre-test scores. This was the case for both KoC (pre-test: MC-KoC = 79.22, MI-KoC = 67.45, $t = 3.74$, $p > .05$) and RoC (pre-test: MC-RoC = 75.24, MI-RoC = 65.79, $t = 3.31$, $p > .05$). Concerning mean gain KoC scores, there was a great difference between intervention and comparison groups. While the mean gain was .65 in comparison group, it was

11.84 in intervention group. Similarly, mean gain scores of RoC of intervention group was greater than comparison group. The mean gain score of comparison group was 2.35, but it was 11. 39 in intervention group. In order to control this difference, ANOVA test was conducted with mean gain scores while analyzing post-test scores.

The post-test KoC and RoC gain scores (post-test-pre-test) were presented with ANOVA results in Table 4.5. Intervention versus comparison group was considered as independent variable. The results showed that the increase in KoC and RoC scores for participants in intervention group (*MGain-KoC* = 11.843, *SE* = 2,149; *MGain-RoC* = 11,390, *SE* = 2,140) were significantly greater than for participants in the comparison group (*MGain-KoC* = ,654, *SE* = 1,962; *MGain-RoC* = 2,349, *SE* = 1,953): *FKoC* (1, 31) = 14,790, $p < .01$, and *FRoC* (1, 31) = 9,741, $p < .01$.

Table 4.5. ANOVA for gain scores with treatment as the between subjects factor

Source	Sum of squares	*df*	Mean square	*F*	*p*	Partial Eta Squared
KoC gain						
Treatment group	1024.412	1	1024.412	14.790	.001	.640
Error	2147.236	31	69.266			
Total	4258.824	33				
RoC gain						
Treatment group	668.819	1	668.819	9.741	.004	.634
Error	2128.559	31				
Total	4174.041	33				

Table 4.6, which is the inspection of the 95% confidence intervals around each mean gain, shows that there was a significant increase in KoC and RoC scores for participants in the intervention group (the interval does not include zero) and no significant change in these scores for participants in the comparison group (the interval includes zero). These results let us to reach the conclusion that four

metacognitive strategies, which were writing reflection papers, researching the development of the ideas of peers, solving case studies and constructing concept maps provided PSTs to improve their metacognitive awareness both in terms of the knowledge and regulation of cognition.

Table 4.6. MAI mean gains, standard errors and 95 % confidence interval for the intervention and comparison groups

			95 % confidence Interval	
Group	Mean Gain	Standard Error	Lower Bound	Upper Bound
KoC				
Intervention	11.843	2.149	7.460	16.226
Comparison	.654	1.962	-3.347	4.654
RoC				
Intervention	11.390	2.140	7.027	15.754
Comparison	2.349	1.953	-1.634	6.333

CHAPTER 5

CONCLUSIONS, DISCUSSIONS, IMPLICATIONS, RECOMMENDATIONS

This chapter provides a discussion of the findings of this research. The purpose of this study was to explore the effect of using metacognitive strategies embedded in explicit–reflective NOS instruction on the development of pre-service science teachers' NOS understandings. Two major research questions guided this study. Each will be discussed respectively in the sections following sections.

1. What is the effect, if any, of using metacognitive strategies embedded in explicit–reflective NOS instruction on the development of pre-service science teachers' understandings of NOS?

    a. What are PSTs' NOS understandings before NOS instruction?
    b. What are PSTs' NOS understandings after NOS instruction?

2. What is the effect, if any, of using metacognitive strategies embedded in explicit–reflective NOS instruction on the development of pre-service science teachers' metacognitive awareness?

Major findings and their interpretation are presented in this section. At the end of the chapter, implications and recommendations about the findings are given.

5.1. Discussions and Conclusions

5.1.1. Pre-Service Science Teachers' VNOS-C Pre-Test NOS Understanding

Both comparison (88.9%) and intervention group (100%) participants held naïve views of NOS before NOS instruction. Pre-test findings of the present study supported the idea that PSTs' misconceptions and general views about the targets of NOS aspects were similar to the common misconceptions in the literature (Abd-El-Khalick, 2005; Abd-El-Khalick & Lederman, 2000a, 2000b; Clough, 2000; McComas, 1996, 1998; Ozdemir, 2007; Yalcinoglu & Anagun & 2012). For example, Yalcinoglu and Anagun (2012) studied with 29 pre-service science teachers and found that majority of PSTs held naïve views of the targeted NOS aspects at the beginning of the study. Also, in Abd-El Khalick and Akerson's (2009) study majority of the participants held naïve view in all aspects of NOS. In the present study, participants also gave inconsistent responses with the definitions of NOS and majority of them held naive view of NOS. Therefore the general misconceptions in the literature which lead participants to have naive views were that they believed there is a hierarchical order between theory and law (Abd-El-Khalick, 2005), science is objective that it can not be affected by individual biases (McComas, 1996, 1998); the perception of scientific knowledge is absolute (McComas, 1996, 1998); scientific knowledge is procedural and do not include creative ideas (Abd-El-Khalick & Akerson, 2004); there is a universal procedure which is boring, sterile and matter of fact (McComas, 1996, 1998); scientific knowledge is beyond the social and cultural influences (Abd-El-Khalick, 2005); they were unaware of the bases of axioms in scientific knowledge and assumption orpresuppositions of science (Clough, 2000).

In the present study, majority of participants held naïve views in all aspects of NOS, but the pre-test results revealed that theory vs. law (100%), tentativeness (94.4%) and inferential (88.9%) aspects of NOS were the highest naïve percentages in comparison group. Theory vs. law (100%), inferential (100%) and empirical (86.7%) aspects of NOS were the highest naïve percentages in intervention group.

As all of the participants held general misconceptions about all of the aspects of NOS, it would be interesting to ask the possible reasons of the most naïve views which were theory vs. law, inferential, tentativeness and most partially informed one creativity. First of all, it is inevitable to ask the reason for the distinction between a scientific law and theory aspect being the highest naïve views of NOS in both groups. One of the possible explanations may derive from the perception of hypothesis which was defined as "educated guess" (MsComas, 1996, 1998). Therefore, there exist such a hierarchical view that hypothesis is the most unknown and the suspicious one; when hypothesis get some proof it become theory but it is still have suspicious, and at the end if it is proven it becomes law (Jones, 2010). Another explanation may drive from the meaning of "theory" that has a sense of explanation for crime senses and secret events (Jones, 2010). They believed that theory may give a sense of ideas which are waiting to be proven; especially the suspicious ideas. Theories are considered as lacking any real scientific proof. Therefore, the proper meaning and usage of theories could not be understood by pre-service teachers while explaining phenomena and making predictions in new observations (Jones, 2010).

Tentativeness aspect of NOS was also one of the highest percentages of naïve views. "Tentativeness" has a negative connotation referring to instability; however it is the opposite of meaning in science (Dogan, 2011). Therefore, PSTs cannot think science to be changing constantly, they believe that scientific knowledge gives the exact results and they cannot change. There was a general perception of "absoluteness" in scientific knowledge. Similarly, PSTs failed to understand the inferential aspect of NOS. They believed that scientific knowledge emerged and also developed by direct observation that facts speak with themselves (Abd-El-Khalick, 2005). This may derive from the tendency of thinking if something is observable, it is provable, and so it is true.

On the other hand, the result of the study indicated that creative aspect of NOS was the highest partially informed view of NOS both in comparison (55.6%) and intervention group (47.7%) in pre-test results. They believed curiosity which is the origin of exploring the unknown derive from imagination and creativity and scientists use them in some parts of scientific method. However Akerson, Morrison and McDuffie (2006) reported the naïve views of the pre-service science teachers about the role of imagination and creativity. They considered science as procedural and determined than being creative (Abd-El-Khalick & Akerson, 2004; Lederman et al., 2002). They believed that scientific knowledge could be explored by induction, however they should keep in mind that imagination and creativity are musts for making inferences in observations and construct generalizations (McComas, 1996, 1998).

These results lead us to think that it is actually difficult to change the general idea which people have tendency to believe. The results also emerged that participants were educated with misconceptions up to that age and did not have any NOS knowledge in their education life. Therefore, many studies have been investigated with different instructional methods and strategies in order to improve NOS understandings of PSTs, the present study also aims it.

5.1.2. Pre-Service Science Teachers' Post-Test NOS Understanding

Post-test results showed that naïve views of general NOS profiles decreased 77.8% in comparison group and decreased 93.3% in intervention group. There was a substantial increase in informed views (53.3%) of general NOS profile in intervention group. However, it is worth pointing out in post-test results that more increase occurred from naïve to partially informed views rather than naïve to informed views. For instance, in intervention group the informed views of tentativeness, inferential and social and cultural influence aspects of NOS percentages were under 50% and only creative aspect of NOS percentages in comparison group was above the 50%. This must be resulted from the shortness of the intervention period that if it was longer this increase might change most of other PSTs views to informed views of NOS.

Participants in both groups showed resistance to change their ideas about inferential, social and cultural influence and tentativeness aspects of NOS. One of the possible explanation for the lower increase of inferential aspect is that “pre-service teachers hold the notion that seeing was knowing” (Yalcinoglu & Anagun, 2012, p.127). Therefore, it is important for students to have more activities about observation and inferences and the difference between them. Similarly, about 22% of the PSTs from both comparison and intervention groups were still holding naïve views that scientific knowledge is not affected from social and cultural beliefs. This may drive from the negative perception that scientific knowledge assimilates cultural beliefs and social values (Jones, 2010). As scientific knowledge develops, people think they will lose their routine life styles which is unwanted because of being unknown. In order to provide more increase on social and cultural influence aspect of NOS, it was important to give the idea that scientists are affected from their background and culture, because curiosity especially derives from needs which are personal or cultural. For instance, there are many examples in the literature that show how scientific knowledge was developed. This is because of those social needs or rather how scientific knowledge affected by the cultures and lead substantial changes. These examples may have encouraged PSTs to understand these aspects clearly.

Moreover, 28% of the PSTs from comparison group, 13% of the PSTs from intervention group could not still accept that scientific knowledge is tentative. The idea of “absoluteness” makes scientific knowledge more valuable and trustable. Therefore it may be hard to accept such an important thing to be changeable. Tentativeness aspect may have supported by interesting examples from our lives. As the participants are familiar with the examples on their lives, they would be easier for them to understand idea base on the aspect.

Although some of the aspects showed lower increase, the majority of the participants’ views about the NOS aspects showed an increase in both comparison and intervention groups. Especially, they became aware that scientists use their imagination and creativity in all steps of their investigations; law and theory are different conceptions and one can not become the other one. Scientific facts are empirically based and subjective.

The findings of present study are parallel to the findings of previous studies suggesting that the explicit-reflective NOS instruction is effective in improving students' NOS understandings (e.g. Abd-El-Khalick, 2001; Abd-El-Khalick & Akerson, 2004; Akerson et al., 2006). The positive effect of explicit reflective NOS instruction could be seen from the gain scores of both comparison and intervention group participants' post-test scores. As it was mentioned in method part, explicit reflective NOS instruction was used in both groups, but metacognitive strategies additionally used only in intervention group. The increased gain scores of both groups showed that explicit reflective NOS instruction increased the NOS understandings of the participants. In explicit reflective NOS instruction seven NOS activities addressed the function of, and relationship between, scientific theories and laws, differences between observation and inference, and the empirical, creative, imaginative, and tentative nature of scientific knowledge, targeted the theory-ladenness and the social and cultural embeddedness of science. In other words, participants held generic NOS activities about each aspect, they discussed their ideas during the activity and they reflected their ideas at the end of the activity. Most of the times, they could not guess the possible results during the activity, they wondered the outcomes and they surprised at the end of the activity. Therefore they were asked the reasons and tried to understand the logic behind them. During all activities the instructor guided participants to explicitly discuss the related phenomena about the aspects in order to make them reflect their ideas (Lederman & Abd-El-Khalick, 1998).

As mentioned, explicit reflective approach provided a positive change in NOS understandings of PSTs in both groups. When the changes analyzed, the greatest increase in comparison group was in theory vs. law (83.3%) aspect of NOS. In intervention group, theory vs. law and inferential aspects of NOS showed a substantial increase from naïve view to partially informed and informed view of NOS. However, it is crucial to note about this increase that although participants wrote the difference between theory and law, they were the memorized definitions of these terms. It was clear from the responses that only a few of PSTs could give examples to related questions. Participants in intervention group claimed their idea has changed about this aspect, but they explained in their interviews that they still could not get the logic behind it. They mentioned that up to their age they were taught that theories are the weaker forms of laws. So, in order to change such a rooted idea, it is important to explain this difference by making them to think deeply.

The findings further illustrated that training in metacognitive strategies improve the effectiveness of explicit–reflective NOS instruction in developing the understanding of NOS (Abd-El-Khalick & Akerson, 2009). Participants with high metacognitive knowledge accurately know what they know well and what they do not know well. As metacognition could be improved through training (Chi, Deleeuw, Chiu & LaVancher, 1994; Thiede, Anderson & Therriault, 2003), metacognitive strategies provide students to get metacognitive thinking. Four metacognitive strategies are used in this study: reflection papers, concept maps, responding case study and responding to researching the development of the ideas of peers.

Regarding metacognitive awareness level there was a significant increase in both KoC and RoC scores of intervention group after the use of four metacognitive strategies. Therefore, consistent with the previous studies, it was not difficult to conclude with the findings that metacognitive strategies were effective in improving students' both metacognitive awareness and understanding of NOS (Brenna 1995; Palincsar & Brown 1984; Roberts & Erdos, 1993; Smith, 1994; Abd-El- Khalick & Akerson, 2009).

The effect of metacognitive strategies were clear in post-test results that, in intervention group, the highest increase from naïve view to informed views was 80% in theory driven aspect of NOS and 73.3% in theory vs. law aspect of NOS. Similarly, the number of PSTs' in intervention group who held informed view of NOS were more than PSTs' in comparison group in terms of all aspects. In other words, three aspects which were theory laden, creativity, theory vs. law aspects were more than 50% and empirical and inferential aspects were near to 50% informed views.

This increase derived from four metacognitive strategies. Firstly, one of the metacognitive strategies used in the study was researching the development of the ideas of peers. It was provided participants to reflect on their own ideas. After doing concept maps, participants expected to exchange their concept maps and question each other about the revisions they made on their second concept maps. By this way, participants reflected their ideas explicitly. Moreover, the instructor provided participants to reflect on their NOS views during the lessons by organizing, presenting, and leading discussions on NOS aspects. All these might contribute to the development of appropriate NOS views among PSTs. In addition, other metacognitive strategies which were reflection papers, concept maps and case study seemed to help PSTs improve their NOS understanding. Participants as illustrated in results parts; gave answers to the metacognitive questions related to NOS in their reflection papers, constructed concept maps regarding science and solved a case study showing that their NOS understanding increased. This result was consistent with the previous studies (Abd-El-Khalick & Akerson, 2004, 2009; Peters, Kitsantas, Baek, & Bannan Ritland, 2007).

In intervention group, PSTs were experienced to write reflection papers as metacognitive strategy. This experience seemed to provide participants to compare their previous knowledge with the new one. Therefore, they had a chance to self monitor and do self assessment. For instance one of the PSTs explained his changed ideas as follows: "I thought scientists are objective and so all of them say the same thing about a scientific issue…Now I know that they are subjective and their thoughts change with their background knowledge and environment."(12 I). This change showed the internal feedback about the current progress, future expectations of progress or connecting new to old (Flavell, 1979).

Concept maps and case study also seemed to improve metacognitive awareness of the PSTs. Participants associated and wrote the first things coming to their minds into their first concept maps. However, most of them added different NOS aspects or NOS related words into their second concept maps. At least they learnt that NOS is an important part of scientific knowledge. Therefore, it is clear that concept mapping is a significant tool for PSTs to develop meaningful NOS learning (Heinze-Fry & Novak, 1990; Okebukola, 1990; Thomas & Barksdale-Ladd, 2000).

Metacognitive strategies are very important because as students become more skilled at using metacognitive strategies, they gain confidence and become more independent as learners (Brown et al., 1983; Flavell et al., 2002; Livingston, 1997). Therefore, responding to a case study provided participants to find the best way of solving the problem. PSTs thought how they could overcome such kind of problem in their future classes. Participants' responses were creative and meaningful which shows case study helped them to become more skilled at using one of the metacognitive strategies. Case study was about the difference between "observation" and "inference", PSTs who were divided into groups made good action plans in order to solve the case. Therefore, it is clear that participants will actually use their plans in their future classrooms. Although there was a lower increase in inferential aspect of NOS in post-test results, the case study action plans of students were really successful.

Finally but more significantly, during the intervention phase, participants were encouraged to discuss their views in the class. As it was clear in pre-test results, NOS aspects were so strange for students that they had learnt the opposite of the aspects up to their age. Therefore, discussions during NOS instruction enhanced participants' cognitive and operative metacognitive dimensions about NOS aspects (Abd-El-Khalick & Akerson, 2009). Inevitably, participants' compared their old knowledge with the new one and tried to fix the logic behind NOS aspects.

In the light of above discussion, as it was discussed in Abd-El-Khalick and Akerson's study (2009), there was a need to search if metacognitive strategies were most useful for promoting informed views of NOS. Therefore, in present study, it was aimed to develop the pre-service science teachers' understanding of seven

NOS aspects. However, the findings of this study demonstrated that the intervention group's post-test views of all seven aspects of NOS were also not significantly higher than those of participants in the comparison group. It means the result is inconsistent with Abd-El-Khalick and Akerson's (2009) study in which they indicated that increased metacognitive awareness lead to the development of pre-service science teachers' understandings of NOS. Although, all of the criteria and the mean gains of each aspect showed there was a substantial increase in PSTs' NOS understanding, chi-square results showed statistically no significant difference between comparison and intervention group participants' NOS understandings. The result of the study showed that more research is needed to find the effect of using metacognitive strategies embedded in explicit reflective NOS instruction on the development of PSTs NOS understanding.

5.2. Implications and Recommendations of the Study

Research have consistently indicated that teachers do not have a deep understanding of science (Abd- El-Khalick & Akerson, 2004; Akerson, Abd-El-Khalick & Lederman, 2000; Bianchini & Colburn, 2000; Chin & Brown, 2000; Nott & Wellington, 1998). Therefore, science teacher educators need to find ways to help elementary teachers develop informed views of NOS. In addition, an explicit-reflective approach has been found to improve elementary teachers' conceptions of NOS (Abd-El-Khalick & Akerson, 2004; Akerson et al., 2000). In this approach it is important to encourage the PSTs to understand the NOS aspects by different hands on activities and discuss the results of each activity. Also, underlining the key points' and confusing parts of the activity have great importance. Therefore, science teacher educators provide PSTs to reflect their ideas, and make the questions in their minds clear by explicit reflective discussions.

It is recommended that any intervention related to NOS teaching in classroom requires teachers and pre-service teachers to be active in that intervention. It is important to get the knowledge meaningfully that teachers and pre-service teachers should explore NOS conceptions, challenge their old knowledge and negotiate with each other to fulfill the gaps in their minds. All these features are promoted by metacognitive thinking.

This study had implications regarding teacher education. As it is claimed that there is a need for different ways of teaching NOS, so using metacognitive strategies would be an effective way for it. Four of these metacognitive strategies and explicit reflective NOS instruction in present study provided a substantial increase in NOS understandings of PSTs in intervention group. As recommended in Akerson, Morrison and McDuffie's study (2005) using metacognitive strategies are promising for the development of NOS understanding. As used in present study, asking metacognitive questions in reflection papers provided participants' to question themselves about what they learned; concept mapping provided them thinking in a schema by relating new to old and make connections between them (McAleese, 1998); case study encouraged them to make an action plan for the encountered problem about NOS aspects (Wahbeh, 2009). The integration of these strategies into teacher education programs may be efficient to improve their development and achievement in a various content areas (Palincsar & Brown 1984; Roberts & Erdos, 1993; Smith, 1994). When participants begin to think about their thinking, they could get the knowledge in a meaningful way and become independent learners (Peters, 2004). Moreover, it was found that after NOS instruction some of the PSTs have some difficulty to understand certain NOS aspects including tentativeness, social and cultural influence and theory vs. law aspects. Therefore, it would be beneficial for PSTs to provide more time for teaching of these NOS aspects by using generic and content embedded NOS activities coupled with class discussion (Lederman & Abd-El-Khalick, 1998).

In the present study, the substantial increase in PSTs' NOS understanding could not be seen statistically. On the other hand, Abd-El-Khalick and Akerson's (2009) study indicated that improved metacognitive awareness provide improved understandings of NOS among the intervention group participants. Therefore, more experimental studies are needed to find the real effect and causal link between increased metacognitive awareness and developed NOS understanding. The sample size of the intervention and comparison groups was one of the limitations of the present study. The number of students' should be equally formed. Also, the period of the study could be extended to at least 2 semesters in which the effects of metacognitive strategies would be seen well. In the future research, other metacognitive strategies such as study skills, note-taking and time management techniques may also be used in order to increase participants' NOS understandings more. Therefore, metacognitive thinking of PSTs regarding NOS would be promoted.

The use of the VNOS-C in this study provided more useful data to examine participants' views on more specific aspects of NOS. However, there was an apparent lack of consistency or common constructs in the scoring participants' responses on the VNOS-C questionnaire. Research is necessary to standardize and validate a common scoring rubric to evaluate pre-service teachers' understanding of NOS. This rubric would allow understanding NOS comparisons across studies and present a larger data set in which to apply appropriate research tools to uncover related factors and conditions.

In addition, one of the logical recommendations could be for teacher educators that this study could be designed professionally for implementing teacher education courses. In other words, the teacher education courses may be enriched for pre-service teachers to get the magnitude of NOS teaching. As teachers and pre-service teachers contextualize the importance of learning and teaching NOS, this would inevitably affect their future classroom practices.

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APPENDIX A

VIEWS OF NATURE OF SCIENCE QUESTIONNAIRE, FORM C (VNOS-C)

1. Name:______________________________

2. Gender: ❑Male ❑ Female

3. My Grade: ________

4. My GPA: _________

5. My Age:__________

6. Please write down science courses that you have completed in university:

❑ I completed all science courses that are present in the curriculum (If not please specify):

❑ Elective science courses that I completed are:

Instructions

- ❑ Please answer each of the following questions. Include relevant examples whenever possible. You can use the back of a page if you need more space.
- ❑ **There are no "right" or "wrong" answers to the following questions. We are only interested in your opinion on a number of issues about science.**

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?
2. What is an experiment?
3. Does the development of scientific knowledge **require** experiments?
   a. **If yes**, explain why. Give an example to defend your position.
   b. **If no**, explain why. Give an example to defend your position.

4. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence, or types of evidence, **do you think** scientists used to determine what an atom looks like?
5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.
6. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?
   a. **If you believe that scientific theories do <u>not</u> change**, explain why. Defend your answer with examples.
   b. **If you believe that scientific theories do change**:
      - Explain why theories change?
      - Explain why we bother to learn scientific theories. Defend your answer with examples.
7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence **do you think** scientists used to determine what a species is?
8. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these **different conclusions** possible if scientists in both groups have access to and **use the same set of data** to derive their conclusions?

9. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?

a. **If yes**, then at which stages of the investigations do you believe that scientists use their imagination and creativity: planning and design; data collection; after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.

b. **If you believe that scientists do <u>not</u> use imagination and creativity**, please explain why. Provide examples if appropriate.

10. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

a. **If you believe that science reflects social and cultural values**, explain why and how. Defend your answer with examples.

b. **If you believe that science is universal**, explain why and how. Defend your answer with examples.

APPENDIX B

METACOGNITIVE AWARENESS INVENTORY (MAI)

Adı Soyadı:	Her Zaman	Çoğunlukla	Bazen	Nadiren	Hiçbir Zaman
1. Hedeflerime ulaşıp ulaşmadığımı düzenli olarak sorgularım.					
2. Bir problemi çözmeden önce farklı alternatifleri göz önüne alırım.					
3. Çalışırken daha önce işe yarayan yöntemleri kullanmaya çalışırım.					
4. Yeni konular öğrenirken daha fazla zamana sahip olmak için öğrenme hızımı ayarlayabilirim.					
5. Zihinsel olarak güçlü ve zayıf yönlerimi bilirim.					
6. Yeni bir ödeve başlamadan önce gerçekten neyi öğrenmem gerektiği konusunda düşünürüm.					
7. Bir sınavı bitirdiğimde, o sınavda ne kadar iyi yaptığımı bilirim.					
8. Bir ödeve başlamadan önce kendime açık, net ve özel hedefler belirlerim.					
9. Önemli bir bilgiyle karşılaştığımda çalışma hızımı yavaşlatırım.					
10. Ne tür bilgiyi edinmenin önemli olduğunu bilirim.					
11. Bir problemi çözerken her türlü çözüm yolunu					

gözönüne alıp almadığımı kendime sorarım.					
12. Bilgiyi iyi bir şekilde organize edebilirim.					
13. Bilinçli olarak dikkatimi önemli bir bilgiye odaklayabilirim.					
14. Öğrenirken kullandığım her bir strateji için özel bir amacım vardır.					
15. Bir konu hakkında önceden bilgim varsa en iyi o zaman öğrenirim.					
16. Öğretmenimin benden neyi öğrenmemi istediğimi bilirim.					
17. Öğrendiğim bilgiyi iyi bir şekilde hatırlayabilirim.					
18. Duruma bağlı olarak farklı öğrenme stratejileri kullanabilirim.					
19. Bir ödevi bitirdikten sonra o ödevi yapmanın daha kolay bir yolu olup olmadığını düşünürüm.					
20. Ne kadar iyi öğrendiğim benim kontrolümdedir.					
21. Konular ve kavramlar arasındaki ilişkileri anlamama yardımcı olması için düzenli olarak derslerde öğrendiklerimi tekrar ederim.					
22. Bir konuya başlamadan önce, o konu hakkında kendime sorular sorarım.					
23. Bir problemin farklı çözüm yollarını düşünür ve en iyisini seçerim.					
24. Yeni bilgiler edindiğimde, öğrendiklerimin bir özetini yaparım.					
25. Herhangi bir konuyu anlamadığımda başkalarından yardım isterim.					

26. İhtiyaç duyduğumda, öğrenmek için kedimi motive edebilirim.					
27. Çalışırken hangi öğrenme stratejilerini kullandığımı bilirim.					
28. Çalışırken kullandığım stratejilerin ne kadar işe yaradığını değerlendiririm.					
29. Zihinsel yönden güçlü yanlarımı, zayıf yanlarımı telafi etmek için kullanırım.					
30. Yeni bilginin anlamı ve önemine odaklanırım.					
31. Bilgiyi daha anlamlı bir hale getirebilmek için kendi örneklerimi oluştururum.					
32. Birşeyi ne kadar iyi anladığımı doğru bir şekilde yargılayabilirim.					
33. İşe yarar öğrenme stratejilerini otomatik olarak kullanırım.					
34. Öğrenme sürecinde düzenli olarak belli noktalarda durur ve ne kadar iyi anladığımı kontrol etmek için kendimi sorgularım.					
35. Kullandığım her bir öğrenme stratejisinin ne zaman en fazla yararlı olacağını bilirim.					
36. Çalışmanın sonuna geldiğimde, hedeflerime ne ölçüde ulaştığımı sorgularım.					
37. Öğrenirken, konuları daha iyi anlayabilmek için resimler ya da şekiller çizerim.					
38. Bir problemi çözdükten sonra, her türlü seçeneği göz önüne alıp almadığımı kendime sorarım.					
39. Yeni bilgiyi kendi cümlelerimle ifade etmeye çalışırım.					
40. Bir konuyu anlayamazsam, kullandığım öğrenme					

staratejisini değiştiririm.					
41. Öğrenmeme yardımcı olması için bir konunun nasıl organize edildiğine dikkat ederim.					
42. Bir ödeve başlamadan önce ilgili yönergeleri (ne yapmam gerektiğini) dikkatle okurum.					
43. Okuduklarımın daha önceden bildiklerimle ilgili olup olmadığını kendime sorarım.					
44. Kafam karıştığında konu doğrultusundaki varsayımları tekrar gözden geçirim.					
45. Zamanımı hedeflerime en iyi şekilde ulaşabilmek için programlarım.					
46. Bir konuya ilgim olduğunda daha iyi öğrenirim.					
47. Bir konuyu aşama aşama çalışırım.					
48. Konunun ayrıntılarından çok genel anlamına odaklanırım.					
49. Yeni bir konuyu çalışırken ne kadar iyi öğrendiğime dair kendime sorular sorarım.					
50. Bir konuyu çalıştıktan sonra sonra gerektiği kadar öğrenip öğrenmediğimi kendime sorarım.					
51. Yeni bilgi anlaşılır değil ise durur ve üzerinden bir kez daha giderim.					
52. Birşeyler okurken kafam karıştığında durur ve yeniden okurum.					

APPENDIX C

CASE STUDY

You teach 18 students in a self-contained second grade classroom. Your schedule allows you to teach science for at least half an hour every day. In science one child stands out in your mind, Carol, who continues to confuse observation and inference. Carol had low assessments in science from both her Kindergarten and first grade teacher, and she continues to struggle in second grade. Standardized testing indicates there is no learning disability. Previous teachers report that they “like” Carol and she has a good attitude toward school. Carol obviously tries to please you, and completes every task you assign her, applying her best effort. She is charming and has a ready smile. She does not have any behavior problems; instead she encourages others to quiet down and behave when they push limits. Socially, Carol is a class leader with close friends. Others respect her. She is always among the first chosen for activities. On the playground she selects the games and is always the voice of sportsmanship. Carol is doing poorly in understanding the distinction between observation and inference in science. However, you know that it takes intelligence to maintain such exemplary behavior and to be so socially adept in school. Surely a child with this level of intelligence should be able to apply it to an academic task such as distinguishing observations from inferences. In the informal analysis of Carol’s definition of “observation versus inference,” you noted that she continually refers to inferences as observations, such as when she noted in an investigation of snails, “I observed that the snails are scared of me touching it.” When you asked her whether that was an observation or an inference she stated, “The snail tried to go into its shell when I touched it. It does not like the feel of skin. That is my observation—it does not like skin.” On another occasion when Carol was exploring pillbugs she stated that she observed that pillbugs “loved the dark paper.” You again asked Carol whether she was making an observation or an inference. She noted, “The pillbugs stayed on the dark side more. They do not like the light. They loved the dark!” You could tell that Carol is confusing observations and inferences, and realize that she will not do well on your assessment of her ability to distinguish between the two. Carol seems to be very confident that she can distinguish between the two, yet her distinctions are not refined enough to allow her to make reasonable observations followed by inferences appropriate to her grade level.

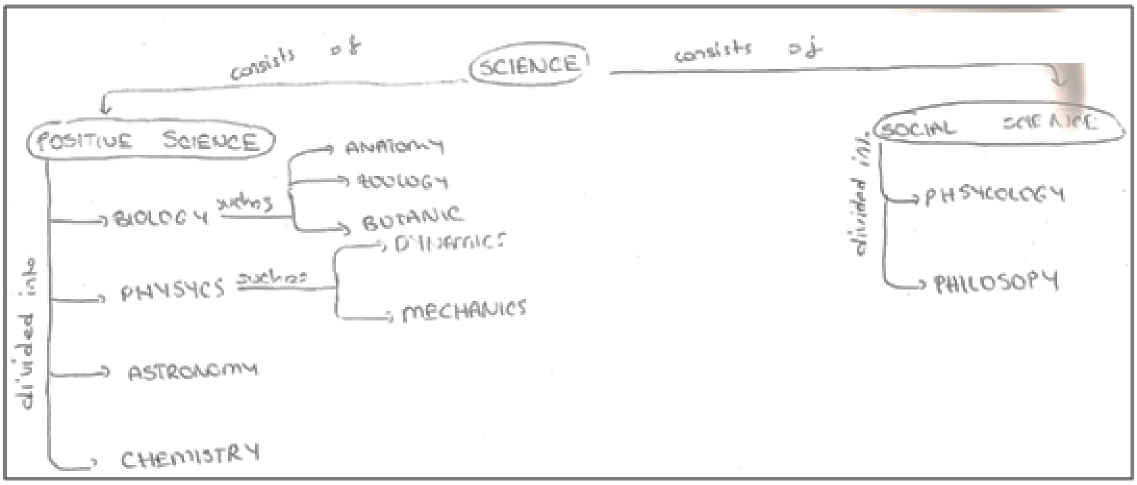
Your Task:

Set up a group of 4-5. Discuss and write a plan of action to help Carol make accurate distinctions between observation and inference.

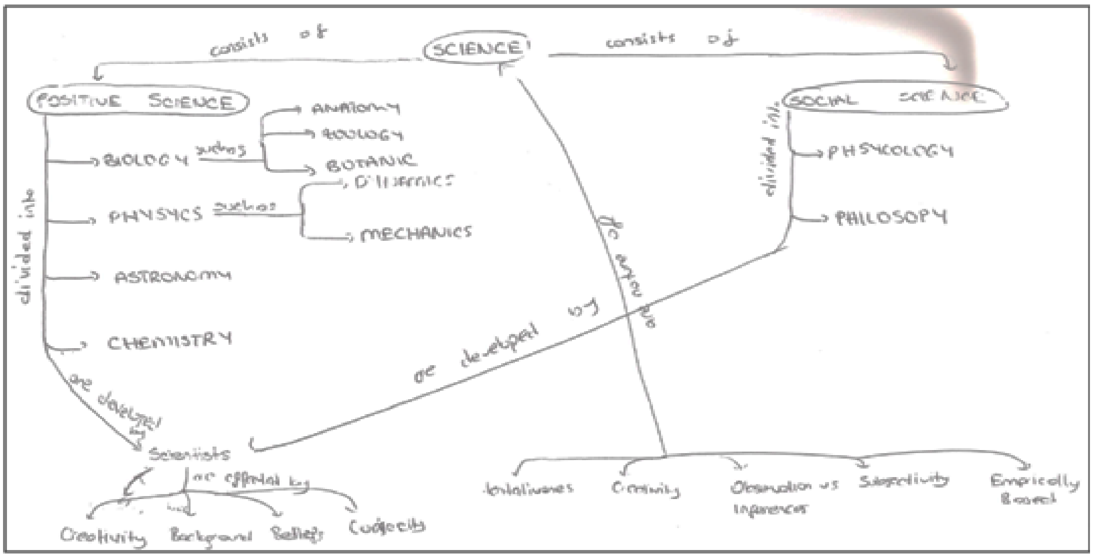
APPENDIX D

EXAMPLE CONCEPT MAPS

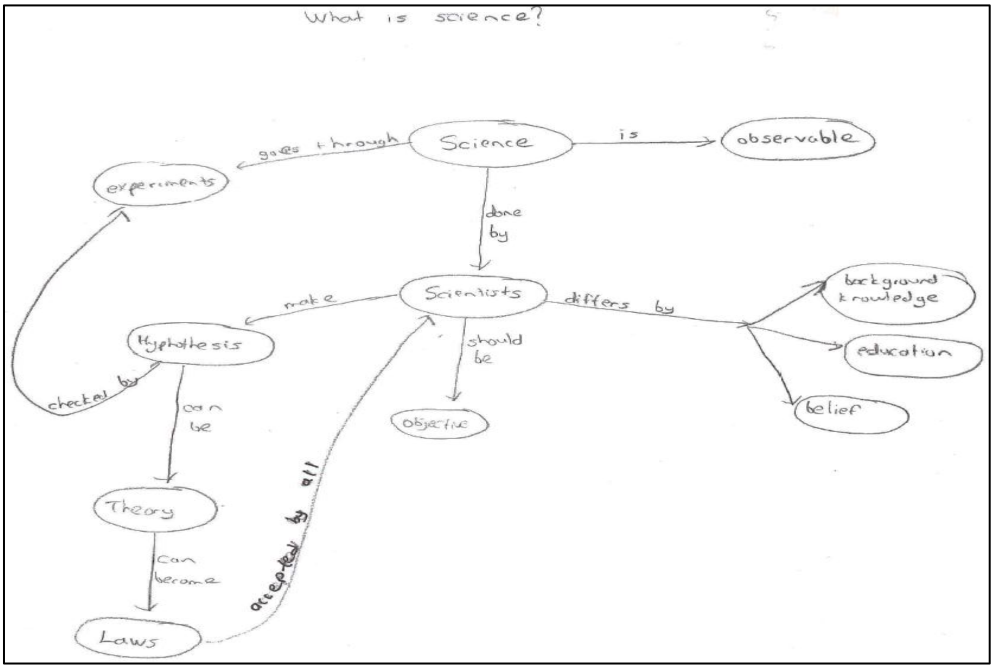
Student A- First Concept Map



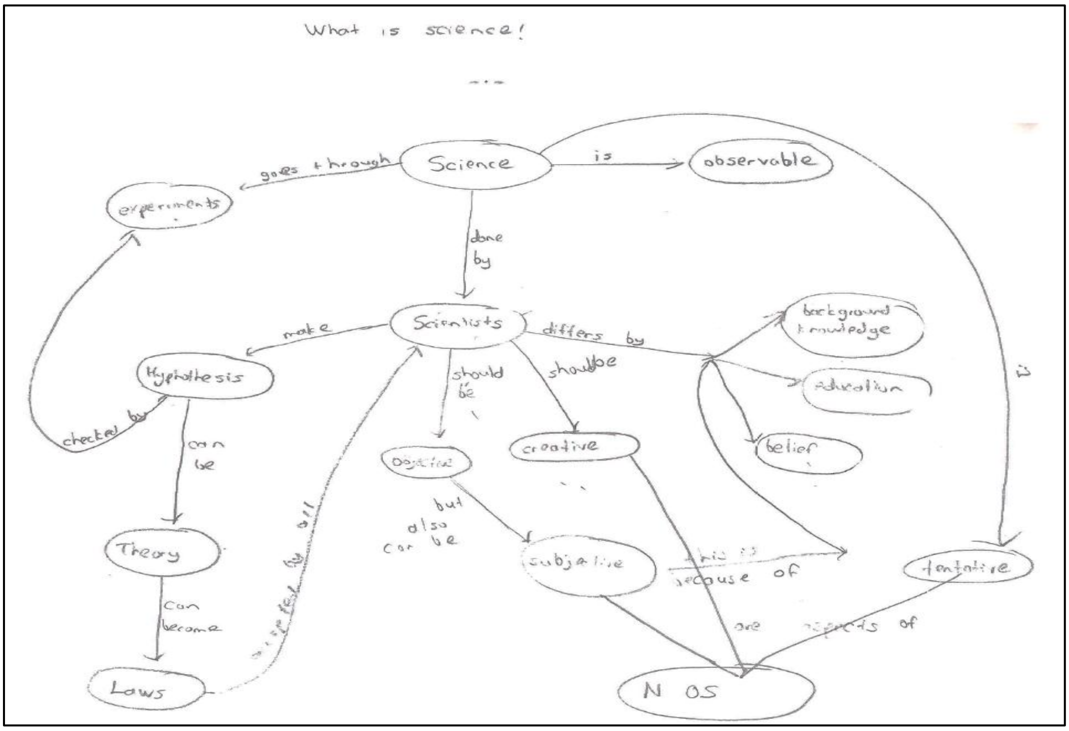
Student A- Second Concept Map



Student B- First Concept Map



Student B- Second Concept Map



APPENDIX E

EXAMPLE REFLECTION PAPERS

8 I- Reflection Paper

One aspect of NOS challenges my views before taking this course and reading this article. I thought scientists are objective and so all of them say the same thing about a scientific issue. It ~~is~~ was a very big conception for me. Now, I know that they are subjective and their thoughts change with their background knowledge and environment.

There are some recommendations, which is mentioned in the article, to help preservice teachers' in retaining accurate NOS views. For instance, it recommends teachers to use metacognitive teaching strategies. It states that metacognitive strategies can help overcome motivational problems and improve understanding of both content and strategies for learning. Moreover, the article recommends that to help preservice teachers attain a higher cognitive position they should use explicit reflective approach. These strategies could include activities such as mind-mapping personal conceptions of NOS over time, coteaching NOS ideas to peers and responding to elementary classroom scenarios to which they need to apply their improved understandings of NOS.

15 I- Reflection Paper

3) **What are the ideas that challenge your previous views about NOS?**

In the forth question it was said that successful scientists are always unprejudiced and objective. However, I know that science is subjective because each scientist has different religion, culture, believes and background knowledge. These features remove scientists from the objectivity. They should be unprejudiced and objective but they cannot be all the time.

The other ideas do not challenge my views about NOS.

4) **Did your views about a specific aspect of NOS change? Why?**

There isn't any change in my point of view about aspects of NOS because I have learned aspects of NOS for 2 years. Also the ideas of this study and my previous knowledge about NOS are the same. Just, I doubted about characteristics of scientist in the 4th question of the questionnaire. I believe that scientist should be objective but I know that they can't be always objective as I told before. Therefore, my opinion about scientists didn't change.

5) **Do the ideas discussed in the article have any implications in science teaching?**

Yes. Because the ideas discussed in the article were about some aspects of nature of science. Students' views about these aspects shows that their views about science. If they have misconceptions about definition of science, NOS and characteristics of scientists, students' understanding about scientific knowledge become poorer. Therefore, science teachers should integrate the aspects of NOS in the science and technology lessons.

In this research one of the NOS aspects that discussed was tentativeness. Tentativeness means that scientific knowledge is subject to change with new observations and ideas. In some lessons this aspect can be integrate to some science subjects such as atomic theories changing process. Therefore, students can easily understand that scientific works can improve with the new information.

The second aspect in this research is social and cultural embeddedness. According to this aspect, science is influenced by society and culture. Almost all lessons science teachers give some examples from daily lives based on subjects.

The third aspect in this research is creativity. According to this research, we can see that most students believe that creativity is one of the characteristics of scientists. This can be integrated to the scientific subjects as not giving the direct information to students but students are expected to reach the information by using their creativities like in the discovery method.

APPENDIX F

EXAMPLE ACTION PLAN TO CASE STUDY

Example 1

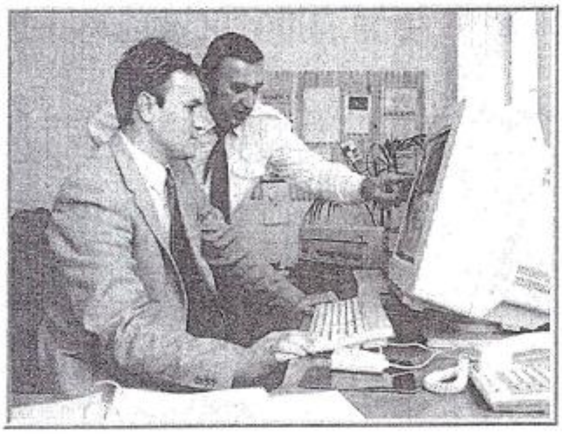
In order to help Carol's troubles with understanding the differences between Observation&Inference , we thought a plan that might be helpful. We planned to show Carol a picture and ask her what she sees.

Before arranging a meeting with Carol , we find 3-4 student or teacher that knows the Observation&Inference very well. We tell others that ;

"Whenever Carol makes an inference , immediately make another inference about the statement that Carol said (and start giggling and laughing by giving the impression that Carol is totally wrong and said something not logical)" → Optinal but effective

"Whenever Carol makes an Observation , tell same as Carol (and acclaim her)"

We planned to show Carol this picture ;



For example , whenever Carol makes an inference like ;

Carol : "Two man is working on a document"

OThers will start immediately telling ;

Student A : "No , I think they are looking photos ,since there exists something looks like a photo document"

Student B: "No , I think they are watching a video , the man standing shows him something"

Student C: "No , I think they are trying to fix the computer , since they look they are trying to solve a problem"

Student D: "No , I think they are trying to calculate something since the sitting one put his right hand on numbers at keyboard , pressing enter button"

Whenever Carol makes an inference like ;

Carol : "The man who is sitting is director , and standing one gives him reports about a duty"

Student A: " No , I think , the standing one is director , since he looks like he is giving orders"

Student B: "No I think , they are friends , because sitting one looks so confident that other one can't be director"

Student C: "No , I think the standing one teaches him how to use a computer application , since he looks like speaking and pointing"

Whenever , Carol makes an observation ;

"There are two man , one is sitting on a chair and other one is standing&showing other something on screen. Also there exists one computer running"

Others will accept it , saying "Yeah you are right" .

Than we tell Carol , " You see , When your friends accepted what you say withouth doubt , it is observation . Observation is contact with the world through the use of the senses. However , when you are not sure about what you say %100 percent , it shows us that there are other possibilities . What you say or what your friends tell might be both true on the basis of what you see, We say it inference. We draw inferences on the basis of observations, or on conclusions drawn from previous observations. We are not very sure what two man do in computer , so what we all say are inferences. However we all agreed on that ; "there are two man , one is sitting on a chair and other one is standing&showing other something on screen. Also there exists one computer running"

APPENDIX G

GENERIC NOS ACTIVITIES USED IN THE STUDY

(1) "Tricky Tracks!" is a generic NOS activity that is based on group discussion and reflection around a picture of certain marks on an overhead transparency. Through the discussion, participants were expected to think about those marks, explain what they are, and present a scenario or a story about what might have happened based on the available evidence in the picture. Participants through the explicit-reflective discussion were expected to distinguish between observation and inference and to realize the theory laden NOS by the fact that their different answers to the same set of evidence are equally valid (Lederman & Abd-El-Khalick, 1998).

(2) "The 'Hole' Picture!" This inquiry activity is intended to reinforce participants' understanding of the following NOS aspects: The observation versus inference, creative and imaginative, and tentative (Lederman & Abd-El-Khalick, 1998). Participants in groups were presented with manila file folders punched with holes of different sizes which allowed participant to see only few parts of colored shapes inserted into the folder. Each group were asked to track the colored shapes that appeared from the holes on a transparency in attempt to identify the "unknown" picture based on the available evidence. Participant were engaged in reflective discussion about how scientists work under similar situation, through which, they are faced with a natural phenomena (represented by the inserted colored shape) and theorize models to understand the phenomena under study using their imagination and creativity (Lederman & Abd-El- Khalick, 1998). The activity was also useful to explicate the tentative and the theory laden NOS aspects.

(3) “Real Fossils, Real Science” aims participants to realize that scientific knowledge is partly a product of human inference, imagination, and creativity (Lederman & Abd-El-Khalick, 1998). Participants were given a fossil fragment and ask them to

make a detailed diagram of it. They traced the outer perimeter of their fossil fragment diagrams on a separate sheet of colored construction paper. Then they complete their fossil drawing on the construction paper containing the fossil fragment diagram using a different color pencil. Each participant drew a the original fossil fragment drawing in one color and the inferred drawing of a complete organism in another color. Participants were guided to discuss the importance of imagination and creativity on scientists' work (Lederman & Abd-El-Khalick, 1998).

(4) "Young? Old?" This is a transparency-based activity through which participants were asked to make sense of the presented pictures in the transparency. In this activity, participants were presented with a picture of an old lady and were asked whether they are able to recognize the face of the young lady in the picture. Through collaborative work and group discussions, participants reflected on the Kuhn's ideas about the role of the "framework" or the "paradigm" as a lens through which participants' (and scientists') observation are filtered. Participants were guided to explicitly discuss how scientists' beliefs, previous knowledge, and training experiences influence their work (Lederman & Abd-El-Khalick, 1998).

(5) “The Aging President” This activity gives participants a feel of what it means to approach a phenomenon with a certain paradigm or mind-set or perspective (Lederman & Abd-El-Khalick, 1998). The activity gives the idea that even though certain facts change, a paradigm lingers on and sets expectations. Participants were shown a caricature of president Regan at the beginning of his term. Then they were shown his other caricatures of the president made at later stages. Participants asked the changes as the president grew older. Participants were guided to explicitly discuss the kind of knowledge, training, experiences, and expectations that scientists bring into an investigation affect what they discern in the available data (Lederman & Abd-El-Khalick, 1998).

(6) "Tube", “Cube” and "Black Box" kind of activities through which participants examined a phenomena by making observations, collecting data, drawing inferences, suggesting hypotheses, and constructing models to test the appropriateness of their hypotheses. In “Black Box” 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. Through the "Tube" activity, participants were presented with a tube and knotted ropes that appear on the outside of the tube and move in an "amazing" pattern. In groups, participants were asked to hypothesize and test the arrangement of ropes inside the tube. In “Cube” activity participants were given cubes. All cubes’ same faces were on the bottom. They used the bottom square of the black-line masters to serve as the face on the bottom without turning or lifting the cubes. Participants were asked find what the bottom of the cube was. From both activities participants were engaged in explicit and reflective discussion about the tentative, the empirical, the imaginative and creative, and the theory-laden NOS in addition to difference between observations and inferences. Participants were guided to discuss the implications of these NOS aspects on the way scientist approach science and the scientific knowledge (Lederman & Abd-El-Khalick, 1998).

APPENDIX H

ILLUSTRATIVE QUOTES OF PSTs' NAÏVE, PARTIALLY INFORMED, AND INFORMED VIEWS OF THE TARGET ASPECTS OF NOS IN PRE-TEST RESULTS

Comparison Group Participants' VNOS-C Pre-Test Responses							
	Empirical	Tentative	Theory Laden	Inferential	Creative	Theory vs. Law	Social and Cultural Influence
1	I Science explains everything … eases the life … it is reality. (Item 1)	I Since theories are not certain, they may change after making some experiments. (Item 6)	I This shows us that both two hypothesizes have some missing parts and new evidence should be found. (Item 8)	I [No proper explanation]	I Scientists develop their hypothesis according to their guesses in the planning stage of their investigations. …there are thousands of	I A theory is required to be proven in order to become a law. (Item 5)	II Culture has an enormous effect on science. For example in ancient Egypt, mummification of pharaohs had led to emerge and

					evolutionary theories, but each one is accepted only by their theorists. (Item 9)		development of medicine. (Item 10)
2	II In scientific investigations, observations, experiments and evidences are required. (Item 1)	I [No proper explanation or implication for development or re-interpretation of scientific knowledge]	I [No proper explanation]	I [No proper explanation/implication]	II Scientists must use their creativity. Otherwise we couldn’t achieve explanations for natural phenomena. (Item 9)	I …theories are open to discussion… on the other hand laws are true knowledge that accepted by everyone. (Item 5)	I I believe that science is universal… (Item 10)
3	I Science is about understanding the life and world. (Item 1)	I I believe that scientific theories do change, the conditions of the era let us see something different from the past. (Item	I [No proper explanation]	I [No implication or emphasis for inference based on observation or experiment]	I [No explanation]	I Theory can be changed after an exception is found. But law cannot be changed. (Item 5)	I Science is universal. Mendel’s law is not just for our culture or social values. (Item 10)

		6)					
4	II Science is a bunch of knowledge which tries to explain natural phenomena via observations and experiments. (Item 1)	I Scientific theories may change if there is no supporting evidence through experiments. (Item 6)	I [No recognition for subjectivity]	I I think scientists are 100% sure of the structure of atom. (Item 4)	II …scientists use their creativity in planning and design and after data collection. …they use their creativity to analyze the data (after data collection)… (Item 9)	I Scientific theories are based on assumptions, while scientific laws are proven theories via observation and experiments. (Item 5)	II I think science is affected from culture and religion. [ex: Galileo] Also, if you report a view which is opposite of cultural values, same reaction [like as Galileo] will arise automatically in the society. (Item 10)
5	I Science is an arrangement of all researchers about interaction of	II I think it can change because we are still exploring the universe…	I [No recognition for subjectivity]	I There are lots of atom theories by now about its content, shape	II I think scientists use their creativity and imagination	I Yes, there is a difference between a scientific theory	I I think science is universal… (Item 10)

	human with nature. (Item 1)	Scientists believe that there are lots of things that we couldn’t explore yet. …with developing about universe our theories can change.(Item 6)		and other specialties. (Item 4)	during their investigation. It happens in the planning and design stages. …imagination and creativity are important part to start to investigate. (Item 9)	and a scientific law. Scientific theory is just proved by hypothesis but scientific law is accepted by all scientists. (Item 5)	
6	I In my view, science is everything. In every part of life, there is science. (Item 1)	I [Theories can only be changed] if experiment results do not support it. (Item 6)	I [No recognition for subjectivity]	I [No implication or emphasis for inference based on observation or experiment]	II Planning and design, data collection and after data collection; scientists use their creativity and imagination in all	I Scientific theory; [knowledge] to be investigated for absoluteness, scientific law; [knowledge] is proven to be true. (Item 5)	I [No proper explanation]

					these stages (Item 9)		
7	I …science is the pure truth. I mean we don't need to discuss or argue in detail because science is basically and simply what it is… (Item 1)	I Theories change because the next scientists are/were trying to show that the previous scientists are wrong. I mean they just so careful to find a mistake generally thanks to this we see that some scientists can be wrong. (Item 6)	II …I guess that's why they had different ideas why dinosaurs become extinct they looked at the different time periods or maybe *interested in* [emphasis on "interested in"] different way. [Implication for subjectivity] (Item 8)	I [No implication or emphasis for inference based on observation or experiment]	II Of course scientists use their imagination… [+ Indication for "scientists use their creativity in some parts of their investigations"] (Item 9)	I Theory is like a seed in the idea. You just try to explain or think whether it's wrong or right but you are not sure of it. But law, it is truth… (Item 5)	I I think science is universal… (Item 10)
8	I Science is a tool to ease the life and to find solutions for problematic	I Theories always can be refuted because they are indefinite. (Item 6)	I [No recognition for subjectivity]	I [No implication or emphasis for inference based on observation or experiment]	II If we had no creative thinking abilities and constructive skills we couldn't reach	I [Failure to state nonhierarchical relationship]	I I believe that science is universal… (Item 10)

	situations. (Item 1)				solutions… [for natural phenomena] [Implication for constant usage of creativity and imagination] (Item 9)		
9	I I think science is technology and this is the main difference between scientific discipline and other disciplines. If technology improves, science also improves… (Item 1)	I I believe that scientific theories could be changed, because they are still [just] theories; failed to reach certainty. (Item 6) If technology improves, science also improves… (Item 1)	I This situation is still questionable due to missing data… (Item 8)	I [No implication or emphasis for inference based on observation or experiment]	II …without imagination there wouldn’t be any discoveries or inventions. Scientists use their imagination before planning, design and data collection… (Item 9)	I [Failure to state nonhierarchical relationship]	I Science is universal. Science cannot reflect a nation’s social, political and cultural values; it [science] goes beyond the society. (Item 10)
10	I Science gives possibilities to	I Theories change because they	I [No recognition for subjectivity]	I They did a lot of experiments	I They use their imagination	I Theory includes knowledge which	I Science cannot be imposed into

	explain what human being curious about. (Item 1)	include uncertain knowledge. (Item 6)		about nucleus. According to their experiment results, they proved it. (Item 4)	before data collection… (Item 9)	lack of certainty. Scientific law; arises when theories are proven to be true. (Item 5)	social or cultural values. (Item 10)
11	I [No proper explanation]	I [We should learn scientific theories because we are] to find better results. (Item 6)	II They [scientists] have different backgrounds. [That's why] they can see different things from same data. (Item 8)	I …via observations with microscopes. (Item 4)	I [No explanation]	I Scientific theories are exactly true but scientific laws may not be true. (Item 5)	I Data and experiments are universal; so, the results must be same and so, science must be universal. (Item 10)
12	I Science is our most effective way to help us to understand our world and even ourselves… (Item 1)	I We cannot think theories as a law… [Hierarchical failure] due to this reason scientific theories can change. For example	II Yes, there is the same set of data in front of scientists. However, back or old knowledge of scientists are very different from each	I [No implication or emphasis for inference based on observation or experiment]	I …we can imagine and then search and try to explain logically what we study. [Further explanation for development of	I Scientific law is accepted by everyone. Scientific theory is not accepted by everyone; it is discussed and	II In fact, science (should) reflect us how to live more qualified in life. … [Scientific developmental]

		evolutionary theory has many misconceptions… (Item 6)	other. Due to this differentiation, there are two different conclusions from the same set of data. (Item 8)		atomic structure] (Item 9)	accepted by a portion of people. (Item 5)	levels reflect us how the society is… (Item 10)
13	II Science includes evidences and it reflects universal facts [~explains natural phenomena]. Science has to involve experiments and observations. Experiments present evidences for [development] scientific knowledge.	I [Implication of “they change because they are *just* theories”]	II There are two different conclusions because scientists have different backgrounds and trainings. …they have different perspectives, this count too, for different conclusions. (Item 8)	II …as a result of continuing predictions and investigations scientists introduced new theories on existing ones … [Some] atomic particles are retained by sending light beams and tracing the way that they follow.	II Scientists need creativity and intellect in all stages of an experiment [investigation]. [Further explanation](Item 9)	I There is a dramatic difference between theory and law. [Failure to state nonhierarchical relationship] (Item 5)	I [confused] Science never affected by a society’s culture, traditions, lifestyles or beliefs. (Item 10)

	(Items 1, 2 & 3)			[~implication for inference/interpretation] (Item 4)			
14	I Science is a concept that is executed for reaching better life standards and to learn new things. (Item 1)	I [Implication of "they change because they are *just* theories"]	II These scientists have different ideas; this affect them [to reach at different conclusions] (Item 8)	I [No implication or emphasis for inference based on observation or experiment]	I I think they use their creativity in planning and design stages… (Item 9)	I Theories may change, but laws cannot. (Item 5)	II No matter how we wish that science is universal, it is affected by social and cultural environment. (Item 10)
15	I Science is observation of things happening around us. (Item 1)	I Theories don't change. They just can be rejected if opponent idea was proven. (Item 6)	I These differences are because that hypothesis cannot be proven. So everybody can say something about it. (Item 8)	I Their evidences are probably showing things are general. (Item 4)	I They can't use imagination, because they should show the facts to people to prove and imagination cannot be showed.	I Law is more accurate but theory is not proven yet. (Item 5)	I Of course it is universal. If something is proven, everybody should believe that no matter what culture

					(Item 9)		they live in. (Item 10)
16	I Science makes our daily life easier. Evidence makes science different from other disciplines. (Item 1)	I Science is subject to change in time. [Not sufficient explanation] [That’s why] theories may change too. (Item 6)	II Even if people have same evidences, they have different perspectives. Also prior knowledge of scientists directs them into different theories. (Item 8)	I Scientists are sure of the structure of atom. But in near future this may be changed by new information. (Item 4)	II Scientists should use their creativity in planning and design stage. Evaluating the data with different methods may be useful for comparing data… (Item 9)	I Theory and law are different. Law is developed and proven version of theory… (Item 5)	II Science is closely related with cultural and social values. They are always in interaction. (Item 10)
17	III I think science is an inquiry of nature using scientific methods like observation, experiment, hypothesis and conclusion.	I Scientific theories change. Most of times they take U-turn due to further experiments and findings. (Item 6)	I This is possible. Why is that; the scientists might have used the same data but then, the data have been interpreted in different ways.	II Well, scientists are not certain about the atomic composition. The fact is that several experiments carried out and	II Yes, I think they use creativity and imagination during planning and design. …they have some sorts of expectations	I Yes, there is a difference between theory and law. Theory is based on a scientific way of explaining nature with room for a	I I believe science is universal. (Item 10)

	Experiment is…science related matters to give a conclusive result. … [Via experiments] scientists build a new set of theories which are necessary for a new set of scientific knowledge. [Further explanation] (Item 1, 2 & 3)		(Item 8)	different models were developed to explain… (Item 4) …the data have been interpreted in different ways. [Implication for inference] (Item 8)	(hypothesizes) and this expectations are drawn through careful imagination and creativity. (Item 9)	change depending on future findings. Whereas scientific law is a fact about scientific inquiry and generally accepted by scientists without controversies. (Item 5)	
18	I Science is a way of gaining an understanding of the world. It is systematic, questionable,	I It is taught to me that theories will be changed when I was at elementary school but I don't know actual reason.	I These two are the possibilities but they are not only two. There are more possible external factors that have	I [No implication or emphasis for inference based on observation or experiment]	I Yes, they use their imagination while planning. Especially, guessing something	I A scientific law cannot change but theories could be… (Item 5)	I Technology is the thing which makes science universal. Technology is developing with

	organized and concrete. (Item 1)	(Item 6)	caused dinosaurs ‘extinction. (Item 8)		happened at past. If a person doesn’t use the imagination, he can’t wonder something, so he can’t be a scientist. (Item 9)		the help of the science. So science is universal. (Item 10)

Intervention Group Participants’ VNOS-C Pre-Test Responses

1	I Experiments are the most important ways which directs the scientists. Scientific knowledge is changed by experiments. Scientists try to prove the theories by experiments.	I Science is both universal and personal. Also, science can be changed by different points of views. However, in physics, chemistry, biology and astronomy scientific knowledge is	II Scientific knowledge can change according to different views and experiments. (Item 3)For instance in our experiments only some students reached the exact result, but we found different results. (Item 7)	I For instance, the result of an experiment depends on how you found it. (Item 6)	II Imagination and creativity are important factors that develop scientific knowledge. Scientists imagine, then wonder and use their creativity. Hypotheses are the products of	I Theories can change, but laws do not change. Theories should be proved by experiments and scientists’’ ideas, then become laws. (Item 5)	II Science may reflects social and cultural values, because scientists have own values and cultures that their studies are affected by them. (Item 10)

	(Items 2 & 3)	definite. (Item 1)			imagination and creativity. (Item 9)		
2	I Science is a fact that develops according to people's needs and efforts, also aims to explore the unknown. Science represents the total knowledge of mankind. Science deals with concrete and provable events and knowledge. (Item 1)	II People cannot reach the whole knowledge at any time that as the mankind survive scientific knowledge will change. As scientific knowledge can change, all knowledge can change, too...as technology and thoughts of people change, theories also change. (Item 6)	I Scientific knowledge is interpreted in different ways, therefore scientists reach different results. (Item 8)	I [No accurate explanations]	I Creativity means variation, and science also means variation. (Item 9)	I Any knowledge is definite, and can be accepted as true according to time and conditions. So, how can we call any knowledge as law, if it changes when conditions change?(Item 5)	I Science is a fact that is valid in everywhere. (Item 10)
3	I	II	I	I	II	I	I

	Science is the key factor that provides a society to learn and develop. Science increases the life quality. (Item 1)	Science is not dogmatic. A theory which is accepted as true now may be accepted as wrong years later. Science always develops and changes. Science can be challenged every time. (Item 1)	[No accurate explanations]	We cannot be a hundred percent sure about the things that we haven't seen yet. Therefore, we are assuming the atom's structure in that way. (Item 4)	Scientists have a big imagination ability and desire to learn. If they weren't like that, they wouldn't be successful in such challenging areas. [Ex: Newton] (Item 9)	Scientific law is proved by experiments and we are sure about its reality, but we have doubts about theories so that we cannot be sure about its correctness. (Item 5)	Science is universal, because all theories are valid all over the world. For that reason all the people ultimately will reach same laws. (Item 10)
4	I Science is the most important factor that provides us to recognize the universe. (Item 1)	I Theories change, different experiments give different results. (Item 6)	I [No accurate explanations]	I [No accurate explanations]	II Scientists use their creativity and imagination in planning and design parts of an experiment, because they have to select their way carefully. After they collect data, creativity is also	I Scientific laws are proved and definite, but scientific theory has not proved and accurate knowledge. (Item 5)	I Science is universal that scientific laws do not change according to place. Therefore culture and social values do not affect it. (Item 10)

					important. (Item 9)		
5	I Science needs thinking, imagination and interpretation. Analyzing is important to understand scientific knowledge. We should approach inductively to analyze the scientific knowledge and understand it deeply. Rational sciences like maths don't involve interpretation,	I If a theory is insufficient or wrong it can be changed. (Item 6)	I [No accurate explanations]	I [No accurate explanations]	II Using different ways in planning, design and data collection of an experiment may change the results of it. These different ways are derived from creativity of scientists. (Item 9)	I Scientific theory is still used but one day it can be proved that it is wrong of insufficient. However, scientific law is exactly true and cannot be changed. (Item 5)	II Science is derived from needs of a society. Society's needs change according to time and place that lead people to do research. (Item 10)

	thinking and discussion. (Item 1)						
6	II Science is a process carried out in order to have a better understanding of life. The difference between science and other studies of life is that science needs facts, experiments and observations in order to carry out the theories and models to explain life. (Items 1 & 10)	I Theories can be changed. The reason is that they are usually based on experiments. Some development in data or some new facts can change a theory. (Item 6)	II The hypothesis is just an interpretation of data and not necessarily true. Also it is a result of the imagination or point of view of the scientist. (Item 8)	I The scientists seem to be considerably certain about the structure of the atom... (Item 4)	I [Not enough explanation]	I Scientific theory is a statement or model that is used to explain some phenomena. A theory can be modified or simply turn out to be wrong. On the other hand, a scientific law applies to all cases and it is not changed. (Item 5)	I I believe it should be universal. Because it is not based on none of the social, political or philosophical aspects. (Item 10)
7	II	I	II	I	I	I	I

	Science depends on observations. Science observes developing events, draw conclusions and emerge new concepts. Everything in our life is the base of scientific results. (Item 1)	It is certain that theories change. If we want to make a scientific study, we should learn the previous studies and the theories about it. (Item 6)	Scientists use the same data and make different hypothesis. This is derived from different inferences and thinking styles. (Item 8)	[No accurate explanations]	Creativity and imagination are used in planning and design part of an experiment. In data collection and analyzing part of the experiment, it should be considered only the data. (Item 9)	Scientific law is the definite version of the theories. .....(Item 5)	Social and cultural values certainly affect science. If evolution theory is censored in a country, it shows that socio cultural values have a big effect on it. (Item 10)
8	I Scientific knowledge takes a real place in students' minds only if they realize how this knowledge carries out. (Item 3)	I If a scientist cannot prove the hypothesis, it must be changed. (Item 6)	I [No accurate explanations]	I [No accurate explanations]	I In some stages, for instance making hypothesis, creativity is used. (Item 9)	I In theory, there are some parts that scientists cannot prove, in law all scientists must be agree in that law. (Item 5)	I Science must be universal, but it is not. It is affected by social, political and philosophical values. (Item 10)

9	I It is a discipline of inquiry that makes us understand the world we live in better in every aspect when studied well. New inventions, discoveries and improvements are made day by day. (Item 1)	I Theories are changed when it comes out to be wrong after applying scientific method. (Item 6)	I Different conclusions are based on their interpretation of the same data. [No further explanation] (Item 8)	I [No implication for inference]	II Science is a discipline of having its own rules, imagination and creativity is not always possible. The best scientists are the ones who can do this...diagnosing an illness that never succeeded by others, finding a cure to an illness require creativity. It requires combining their knowledge of science with their imagination and creativity. (Item	I Scientific theory is something that its correctness is not approved yet. Scientific law, on the other hand, is approved as correct after applying scientific method. (Item 5)	I Science is universal, because all of us live in the same world, same universe... (Item 10)

					9)		
10	I Science is the life. Science is different because it has universally accepted trues and its principles exist on earth. (Item 1)	I Theories are not certain knowledge. If scientists improve ideas about theories they can change. (Item 6)	I Scientists understand and conclude different things from the same data. (Item 8)	I [No accurate explanations]	I Finding a new way to clarify things needs imagination and creativity. However, creativity can exist when a scientist become a good profession. (Item 9)	I Theory is the knowledge which hasn’t been proved. However, scientific laws are proven. (Item 5)	I Science is universal; it doesn’t reflect cultural values, because Newton’s laws are true in every place of the world. (Item 10)
11	I Science makes people’s life easier and provides people to understand life better. Scientific knowledge requires concrete data rather than	II Theories can change, because further experiments about the same topic may invalidate the current theory. Different experiments with	I Different experiments with different views and approaches can develop the theories by eliminating the shortcomings. [No further support] (Item 6)	I Many experiments were made about atom and every experiment constructs a base for the later experiments.	I Creativity and imagination are important in planning and design part of the experiment. (Item 9)	I Scientific theories are the scientific hypothesis that aren’t proven by experiments and observations (Item 9)	I Science is universal, because it is based on concrete data. It is independent from social and cultural values. (Item 10)

	people’s thoughts and beliefs. (Item 1)	different views and approaches can develop the theories by eliminating the shortcomings. (Item 6)		(Item 4)			
12	I Science has the facts about the nature of the world. These facts do not change with time and accepted by everyone. (Item 1)	I Theories cannot be true every time and some scientists are not sure about such theories whether they are true or not. (Item 6) ...these [scientific] facts do not change with time... (Item 1)	I ...science does not change from person to person. It is not an opinion or consideration. (Item 1)	I [No explanation]	II If they [scientists] ask themselves why it is like that and what are the reasons of it [investigation]. They use their creativity in the stage of planning and design. They use it because they do not know anything about their investigation. Without using	I Theory is not accepted by all people or scientists. Law is accepted by all people, cannot be changed or accepted as wrong. (Item 5)	I Science is universal... (Item 10)

					them they couldn’t do anything. (Item 9)		
13	I Science requires a research process. Science is more accurate than other disciplines. Experiment is a must to make the scientific knowledge universal. (Items 1 & 3)	I Theories can change by the help of technological developments. Technology help scientists to realize what they haven’t realize before. (Item 6)	I [No accurate explanations]	I [No accurate explanations]	I Scientists use their creativity after they collect data. (Item 9)	I Theory and law are different. Laws are more accurate and definite, but theories change by developments and learning more. (Item 5)	I Science is universal. ...knowledge is examined in the same way all over the world. (Item 10)
14	I Science required some data. In science there are real events. (Item 1)	I Theories can change over time. With new experiments, ideas it can be seen that theories can change, or they can lose	II In science with the same data, different solutions or conclusions can be found, because each scientist has different	I [No accurate explanations]	II In each steps scientists use their creativity and imagination. Even if they have a small clue, they can reach big	I We cannot change laws. Theory can be changed over time. (Item 5)	II Science is affected by social and cultural values. In some countries because of some

		their accuracy. [No further support] (Item 6)	background, beliefs, and they affect the solution. (Item 8)		conclusions. Of course not just imagination and creativity are enough, but we cannot reject their importance (Item 9)		social or cultural values or religion, science cannot be developed. (Item 10)
15	I Science is the real knowledge that provides us to understand our environment better and shows that everything has a reason. (Item 1)	I The world is changing; therefore it is inevitable for theories not to be changed. (Item 6)	I [No accurate explanations]	I [No accurate explanations]	I Scientists use their imagination and creativity in experiment and observation. Because for experiment to be efficient everything should be ready and sufficient. (Item 9)	I Theory can be proved by experiments and observations. However, laws must be accepted by scientists. (Item 5)	I Scientists want to be objective, but he/she has to adapt his/her environment that affects the scientific studies. (Item 10)

APPENDIX I

ILLUSTRATIVE QUOTES OF PSTs' NAÏVE, PARTIALLY INFORMED, AND INFORMED VIEWS OF THE TARGET ASPECTS OF NOS IN POST-TEST RESULTS

Comparison Group Participants' VNOS-C Post Test Responses

	Empirical	Tentative	Theory Laden	Inferential	Creative	Theory vs. Law	Social and Cultural Influences
1	II Science is a tool which explains natural phenomena. ...experiments needed with observations to support the evidences... [Extended examples	I According to technological developments and equipment, theories change and scientists make new experiments. (Item 6)	III …scientists reach different solutions from same data according to their prior knowledge, education, culture and age. (Item 8) ...every scientist	II Scientists don't see atoms directly. Based on their creativity, they form a model in their minds according to observation and	III Imagination and creativity are used in every part of scientific investigation. (Item 9) Creativity is used when observation	III Theory is the explanation of scientific phenomena; law is the relationship between variables in nature. [Ex: evolutionary theory vs. Boyle's law] (Item 5)	II Scientists grow up with their society's beliefs and culture. Therefore they reflect their culture on their scientific work. The same data may be interpreted

	and explanations about observation and inferences in Interview follow-up] (Items 1, 2 & 3)		has his own explanation for a scientific phenomenon...(Item 7)	collected data. [Implication for inference in interview follow-up] (Items 2, 3 & 4)	and experiments cannot be done especially. (Item 8)	[Extended explanation for theories and laws in Interview follow-up]	differently in various cultures (Item 10)
2	II In science we can construct models, we make experiments...we make observations. Sometimes it is not possible to observe all phenomena in nature...[so construct models] (Item 1 and 3)	III ...with continuing scientific studies, new information is added on the existing one or existing information may be changed. [Implication for re-interpretation of existing knowledge] (Item 6)	III Just like two person who are looking at the same picture but saying/seeing different things, scientists may interpret phenomena from different point of views. This might caused by scientists' societies, cultures, religions or trainings...(Item 8)	II Scientists don't see the atoms directly. After setting and conducting experiments they explain the structure of the atom; by forming a model to explain it. [further explanation] (Item 4)	III Scientists use their imagination and creativity in all parts of their studies. [Ex: Newton's interpretation of falling apple] (Item 9) [Further explanation and examples in interview follow-up]	III ...theory explains the basic principles of a phenomenon and describes it, law draws relationships about this phenomena. [Ex: kinetic molecular theory vs. Boyle's law] (Item 5) At the beginning of the semester I was thinking that theories become laws as they develop. Now I think that there is no such a	III Although science affects all humanity, it is also affected by society and its cultural values ...[Ex: Evolutionary studies vs. religions] (Item 10)

						hierarchy. (Interview follow-up)	
3	II ..although there is no certain step in scientific knowledge, we need to do experiments. (Item 3) In science we do observations and experiments. But it is not always possible to do experiments. For example in astronomy... [Kepler’s works] (Interview follow-up)	II ..in science we cannot mention about certainty. Science is tentative. A theory can be true in a time, can not be true forever. [Ex: atom theory from Democritus, Dalton’s theory, Rutherford’s theory and modern atomic theory] (Items 6 & 7)	III ..they [scientists] have different background knowledge different beliefs and different sides of views. Although there is the same data, scientists can make different explanations to this data. (Item 8) There must be different beliefs, different hypothesis that we can do many researches to achieve the most	II Scientists cannot make rigid observations all the time. In such phenomena they form models to explain it. It is like you are constructing a realistic model of a dinosaur with a few pieces of bones. (Interview follow-up)	III Scientists use their imagination and creativity through their investigation. Science requires different views to the same data according to scientists’ different imagination abilities. (Items 8 & 9) Now I’m aware of that there is no single scientific method... [Interview follow-up]	III Theory and law different from each other. A scientific theory is the explanations of scientific events. A scientific law is the explanations of relationships of scientific events. (Item 5) There is no room for the idea that theories develop and become laws... (Interview follow-up)	II Science reflects social and cultural values, because they affect the environment they [scientists] live. [Ex: the evolutionary theory; the beliefs can affect the scientists’ side of view] (Item 10)

			accurate data. (Item 9)				
4	II Science is a bunch of knowledge which tries to explain natural phenomena via observations and experiments. (Item 1)	I Scientific theories may change if there is no supporting evidence through experiments. (Item 6)	I [No recognition for subjectivity]	I I think scientists are 100% sure of the structure of atom. (Item 4)	II …scientists use their creativity in planning and design and after data collection. …they use their creativity to analyze the data (after data collection)… (Item 9)	I Scientific theories are based on assumptions, while scientific laws are proven theories via observation and experiments. (Item 5)	II I think science is affected from culture and religion. [ex: Galileo] Also, if you report a view which is opposite of cultural values, same reaction [like as Galileo] will arise automatically in the society. (Item 10)
5	II Scientific knowledge is empirically based. Scientific knowledge is gathered from the results of the	II Scientific knowledge is subject to change with further investigations. There is no absolute true.	III Because of subjectivity of scientific knowledge, scientists' beliefs, previous knowledge,	III In nature not all knowledge is observable or measurable. (Item 4) Experiments are not the only way	III Scientists use their creativity and imagination during their investigations in all stages of it. All scientists look the	III There is a difference between scientific theory and scientific law. Theory includes explanations about phenomena, law includes relationship	III Scientific knowledge is socially and culturally embedded, because it is human product, so it is inevitable

	experiments and observations. Other disciplines are not dependent on scientific researches. (Item 1)	(Item 6) New experiments and new data contribute to investigations. (Item 3)	training, experiences and expectations affects their investigations. So they can conclude different results from same data. (Item 8)	to collect data; observation, analysis and speculations are the other ways to collect data. They [scientists] make assumptions and predictions. (Item 7)	phenomena from their own aspects, these make the difference. Scientists make assumptions and predictions by using their imagination and creativity. (Item 9)	among phenomena, but there is not a hierarchical relationship between them, they cannot turn into each other. [Ex: Boyle's law, Kinethic molecular theory] (Item 5)	not to be influenced by society and culture. The values and expectations of culture determine what and how science is conducted, interpreted and accepted.(Item 10)
6	I Scientists make observations and investigations. (Item 7)[No further proper explanation]	II Theories can change with new information. [Further explanation](Item 6)	II Previous knowledge, creativity and imagination of a scientist affect his works. This shows that science is subjective. (Item 8)	I [No proper explanation. No implication for observation, inference or prediction]	III Scientists couldn't obtain exact results from experiments or investigations; that's why they use their imagination and creativity. Scientists use their imagination and	I [No implication for hierarchical failure and different kinds of knowledge]	I Science is not affected by social and cultural values. Because science is a cut above society ...(Item 10)

					creativity in every stage of their investigations. (Item 9)		
7	II ...it [science] changes all the time when new evidences or new theories/opinions found, the previous ones are changed so there is no absoluteness or certainty in this area [science]. ...all scientific knowledge is not based on experiments. Observation is another appropriate way in the	III ...in scientific knowledge tentativeness is not avoidable. (Item 5) ...every scientist can come up with different explanations for phenomena and new evidence or even new interpretations with same evidence can lead to change in scientific theories. [Further explanation] (Item	III Scientists are different persons that have different backgrounds/ beliefs/ social and cultural structures/ expectations/ preconceptions even in observations of scientists there is subjectivity. (Item 1) ...of course scientists end up with different conclusions even though they look	III Scientists can't observe every single data but they can infer and create a model for their explanation and there is no 100% certainty about a phenomenon in science... [Further explanations and example – Rutherford model] (Item 4)	III Scientists use their creativity and imagination during their study since they don't have the chance to observe every detail at this point ...they are generally data based and not copies of reality. [Further explanation and example] (Item 9)	III Law examines the relationship between phenomena, on the other hand theory explains a phenomena and it is more detailed than law. [Ex: Molecular kinetic theory vs. Boyle's law]. ...laws don't have more proved knowledge than theories. They both subject to change since in scientific knowledge tentativeness is not avoidable. (Item 5)	II ...I believe that social and cultural values affect scientific knowledge since their understandings, background knowledge; conception can be affected by their social structure. [Further explanation] (Item 10)

	development of scientific knowledge. (Items 1 & 2)	6)	at the same evidences...(Item 8)				
8	II Science is the system that unknown situations are formulated. Science has observation, inference and experiments.(Item 1)	I Science is tentative. Theories can change and be false. (Item 6)	I Science is subjective, because theories are formed by scientists. They can think false about theory. Therefore, every of them [scientists] want to explain it. However, just one thinks true about theory. (Item 8)	I [No accurate explanations]	II Scientists use imagination and creativity in every process, these help scientists to find the true information. (Item 9)	I There is no difference between theory and law. (Item 5)	I Science is universal. Science refutes social and cultural values. (Item 10)
9	II Science is discipline occurred by or based on some	II Scientific theories change because scientific	II Scientists are subjective. I mean, their prior	III Scientists don't see the structure of an atom	III Scientists use their creativity and imagination at all	III A scientific theory is explanations of a natural phenomenon.	II Science reflects social and cultural values, because

	observations (...and interpreting these observations ...), inferences, experiments made by scientists. (Items 1 & 2)	knowledge is changeable. When some new observations are made or some new evidences are found about a scientific knowledge, theories can change. (Item 6)	knowledge, social and cultural differences affect their interpretations about data. Therefore, they reach different conclusions although they have same set of data. (Item 8)	directly. But they use their creativity and imagination for determining the structure of an atom ...and with the aid of some clues they represent the structure of an atom as we know now. "Some observations and interpreting these observations" [Implication for inference and prediction] (Items 4, 3 & 9)	stages. ...without using them scientific knowledge can not develop. ...scientists use their creativity and imagination and with the aid of some clues they represent the structure of an atom as we know now. (Item 9)	But, scientific law is generalizations or relationships about a phenomenon. [Ex: Gravitational theory vs. Law of gravitation] (Item 5)	science is human work and it is also affected by scientists' social and cultural values. In addition, science is affected by the culture in which it is practiced. [Ex: stem cell treatment] (Item 10)
10	II	I	I	II	II	II	II

	Science is an organized body of knowledge... Science process skills makes science different from other disciplines. (Item 1) Some scientific knowledge does not involve observable things. So scientists cannot make experiments but they can conclude the knowledge. (Item 3)	Some new findings lead to change theories. (Item 6)	Because of scientists' creativity. (Item 8)	They did some experiments about it but they can never see the atom or their parts. According to their creativity and observations they form the structure of the atom. [Implication for forming models and inferences] (Item 4)	Through the design and after the data collection, scientists use creativity. (Item 9)	Scientific theory and scientific law are two different kinds of knowledge. Scientific law states the relationship in a formulated way. Scientific theory is the explanations of laws. (Item 5)	Yes science is socially and culturally embedded so it reflects social and cultural values. For example, in some countries, cloning is forbidden because of religion issues. (Item 10)
11	I	I	II	I	I	I	I
	Science does experiments, observation, make us more sure. (Item 1) ...sometimes	[No accurate explanations]	..because of their [scientists'] prior knowledge, values, beliefs and expectations, they reach different	[No accurate explanations]	[No accurate explanations]	...law explains general things, theory explains more specifically. (Item 5)	[No accurate explanations]

	observations are enough..(Item 3)		solutions from the same data. (Item 8)				
12	III Science is a way to understand the world and creatures which are present in the world. Scientists do experiments and observations. (Items 1 & 4)	II Scientific theories are subject to change. This situation shows us that scientific knowledge can change by collecting more data, doing experiment on the previous knowledge. (Items 6 & 8)	II Using the same set of data, scientists reach different conclusions, because they have different traditions, education and pre-knowledge. (Item 8)	II ..they [scientists] infer or predict how to be an atom. [Indication for evidence] (Item 4)	I [No accurate explanations]	II Theory answers just questions around us. Law explains the relationships between variables. (Item 5)	I Science is universal but scientific knowledge can affect social and cultural background. (Item 10)
13	II Scientific knowledge is empirically based and it makes inferences and	II Yes, theories change. Scientific knowledge is tentative. Both scientific theories	II This example shows us that science is subjective; it changes from	II Based on previous studies, scientists gather new observations and	II Scientists use their creativity and imagination in all steps of their investigations.	III They are both subject to change and there is no hierarchical order among them. [Further explanation and	II ...science reflects social and cultural values. [Ex: evolutionary theory.] (Item 10)

	predictions via observations and experiments. [Further explanation] (Items 1 &3)	and laws subject to change. (Item 5 & 6)	person to person. Scientists' pre-knowledge, experience, expectations and beliefs are different and this may lead them to come up with different conclusions. (Item 8)	data via experiments. New information is evaluated and interpreted, and then a model is formed. (Item 4)	(Item 9)	examples] (Item 5)	
14	I Experiment is the way of learning new things.	II Science can be changed, there is no specific, certain evidence...we can compare and contrast old and new knowledge. (Items 6 & 7) We can not say this	II Scientists have their own pre-knowledge and beliefs. This situation affects the conclusions although they [scientists] have the same set of data. (Item 8)	II Every knowledge can not require experiments, so scientists make inference and prediction. (Item 3)	II Scientists use their imagination and creativity in all parts of investigation. Especially, they use imagination and creativity in missing parts of investigations.	II Theory and law are different. Theory explain relationship of natural phenomena, law defines the phenomena. (Item 5)	III Science *affects* and reflects social and cultural values, because our beliefs, pre-knowledge include social and cultural values. (Item 10)

		claim exactly true or vice versa. (Item 4)			(Item 9)		
15	III Science is knowledge of environment. İt is different than other disciplines of inquiry because it can be observed, experiments can be made. ...scientists try the [natural] phenomena in laboratory conditions. ...for some scientific phenomena, it is impossible to make experiments but still they can be	I Because of changes in technology or new discoveries, scientific knowledge can change. (Item 6)	II Because of subjectivity, scientists can conclude on different things by using the same data. All the people are different, so their points of views are different and can interpret things differently. (Item 8)	II ...for some scientific phenomena, it is impossible to make experiments but still they can be developed. (Item 3) They are not sure. ...by using their creativity, they conclude some atom models. (Item 4)	II When they don't see or observe things, they use their creativity. Besides, they use creativity when they can observe things. They imagine of reasons and effects, so formulate those things. (Item 9)	II There is a difference. Theory explains a phenomenon while law explains relationships in a phenomenon. (Item 5)	II [Since] science is subjective, it can change from person to person as well as from nation to nation. According to different values, beliefs etc different observations or inferences can be made. (Item 10)

	developed. (Items 1 & 3)						
16	III Science organize knowledge in such a way that it can be testable, predictable and be speculating. NOS make science different from other disciplines. Science has body of knowledge, methods ...observation, hypothesizing and inferences. ...rely on observation of natural phenomena. (Items 1 & 2)	II Theories can change. New information can be found and this can require the change or modification of theory. [Ex: Dalton's atom model vs.. isotopes] (Item 6)	III These differences are caused by subjectivity. Scientists have different previous knowledge, experiences, training and expectations. They [These factors] all influence scientist' observation and speculation. They interpret the same data differently. (Item 8)	III Scientists do not observe single atoms. They speculate about what they can not observe. While doing this, they use their creativity and imagination. (Item 4)	III Scientists use their creativity in every step of scientific investigation. They can not make experiments for the astronomy but they speculate by using their creativity. (Item 9)	III Law is statement of relationship among phenomena and theories are explanations of phenomena. [Ex: kinetic molecular theory vs. Boyle's law] (Item 5)	II Science is socially and socially embedded. We can not think them as independent concepts from each other. (ex: sperm banks in west/in Turkey) (Item 10)
17	III ...Scientific	II Scientific theories	III The background,	II The scientists	III Scientists use their	III Scientific theories	III Science reflects

	knowledge is not developed only the way of experiments. Some are developed by only observation, even by inferences and/or predictions. (Items 1, 2 & 3) Scientific knowledge provides explanations and solutions to some of the natural phenomena... [supported by examples] (Item 6)	change when the new evidence, idea, experiment and data are collected. [Extended with species definition example] (Item 6)	prior knowledge, beliefs, expectations, training and previous experiences of the scientists affect their work. So these factors influence the judgment of scientists when carrying out scientific investigation. (Item 8)	are not absolutely sure of how the atoms look like. This is because no scientists have ever isolated an atom for study. So [some parts of scientific knowledge] is developed by only observation, even by inferences and/or predictions. (Items 3 & 4)	creativity and imagination at all processes of scientific investigation right from planning and design to data collection even till their conclusion about the science research or investigation. (Item 9)	generally explain natural phenomena while scientific laws show the relationship between variables in nature. Theories don't turn into law with more evidence or data collected. Both theory and law can change with new evidence. [Extended examples] (Item 5)	social and cultural values. Scientists' environment affects his work and even the environment attracts the attention of the scientists on what investigation he/she is able to engage in. So society of a scientist plays a crucial role in scientists' works. (Item 10)
18	II Science is the process of reaching	II ...they [theories] are not distinct	II Scientist' different backgrounds,	II They use experimental	II ...they [scientists] use imagination	II Yes, they are different. Theories are	II For example, evolutionary theory

answers. Science is questionable, open to change and subjective. ...One can use observations instead of experiments. [Items 1 & 3]	concepts ...we learn theories in order to see the process. If there is a further step one can go on a theory, theories can change. (Item 6)	believes and prior knowledge make different conclusions. (Item 8)	findings. They sent some highly energetic light [beams] through atoms and observe what will happen. Then they create a model depending on their observations. [Implication for inference and prediction] (Item 4)	and creativity while they are planning, design and after data collection. Without imagination and creativity ...there won’t be any inquiry for their environment. (Item 9)	like explanations of the knowledge; laws are observable phenomena in the nature. (Item 5)	is not accepted in Turkey as well as European countries. It is due to the social and cultural and also religious values of Turkish people. (Item 10)

Intervention Group Participants’ VNOS-C Post Test Responses

1	III Science is a process or study in order to explain some phenomena based on evidence and empirical data. Scientific knowledge based on observations. We can not try all the natural phenomena. [Implication for “theoretical models rather than faithful copies of reality.] (Items 1, 2 &3)	II Theories change if they do not fit our new observations and experiments. (Item 6)	III This is subjectivity. They [scientists] use their prior knowledge ...and this effect their studies. (Item 8 & 9) Subjectivity is inevitable. Scientists cannot easily get rid of their background while making investigations and coming up conclusions… (Interview follow-up)	II They [scientists] imagine when they don’t have a chance to do experiments or for old events. (Item 9) It is not possible to get data from direct observations… (Interview follow-up)	III Creativity is needed and can be used in all steps of a study. ... They [scientists] imagine when they don’t have a chance to do experiments or for old events. (Item 9) Scientist may reach genuine results when they don’t follow the common-known scientific method. (Interview follow-up)	III There is no hierarchical order; they are different kinds of knowledge. Theories are explanations of natural world; laws are relationships in natural phenomena. (Item 5)	III They [Social-cultural values and science] are mixed with each other. Social and cultural values influence studies of scientists. Their preferences can change with or their study can be changed in another way by culture. (Item 10)

2	III In order to arrange people’s needs science is used as a process. Science is about how the nature works, what are the basic principles that apply to entire universe. Science is for the questions arise in human kind about what are those principles. Science exits [emerges] for people’s curiosity. (Item 1) Science may require experiments, but in some cases scientists cannot conduct	II Theories change, as the time passes new developments occur, new theories develop or existing ones develop. (Item 6) Scientists always tries to find new things about existing ones.(Item 9)	III Scientists’ background knowledge, experiences, training affects their [scientists’] conclusions. This is subjectivity of science. (Item 8)	III Scientists’ make inferences and predictions based on their evidences and trying to find the best. (Item 4). Scientific theories change since they all depend on our predictions and inferences.(Item 6) ...in some cases scientists come up conclusions without having observations. (Interview follow-up)	III In all parts they [scientists] use their imagination and creativity. They also affect their prediction skills. Scientists always try to find new things about existing ones. It can’t get any further if they don’t create new thoughts. (Item 9)	III Theories are possible explanations to the scientific phenomena. Laws are the relationship among phenomena. [Examples of theory and law] (Item 5) At the begging of the semester I was thinking that theories do not involve certain knowledge...and they become laws when proven. But now I can say that there is no such a hierarchical relationship among them... (Interview follow-up)	II Social and cultural values affect their [scientists’] thanking. It may also limit their thoughts. Cultural backgrounds affects their [scientists’] conclusions.(Items 9 & 10)

	experiments...even in some cases scientists come up conclusions without having observations. (Interview follow-up)						
3	III Science seeks for solutions, explanations also descriptions for natural phenomena. ...but in science no one can claim that there is a one way to reach a theory or there is one truth. Scientific knowledge is tentative and subject to change but in	III Scientific knowledge is tentative and subject to change... (Item 1) Theories can change because they have parts of human imagination or inference for that reason they can be changed in the light of new	III Scientific knowledge is subjective. Every scientist have different point of view due to their different previous knowledge, belief, experience and expectations so that they reach different conclusions otherwise they all	III Some information can be reached by making inference or using creativity.(Item 3) Scientist cannot observe directly structure of atom or electrons neutrons and	III Scientist can use their creativity in all part of their investigations. There is no specific part that scientist turn their creativity on. They can improve, simplify and facilitate all part of their investigation by using their	II Scientific law is a description about observable phenomena and do not give an explanation how these phenomena occur. On the other hand theories give explanations and explain how certain phenomena occurred. (Item 5)	III Science reflects social and cultural values. For example some application in science can be supported in one country and others can reject it. Scientific applications, experiments also improvements are affected by socio-cultural structure of

religion... Scientific knowledge is also empirical based and by using logic one can draw conclusions in scientific research. (Item 1) Some information can be reached by making inference or using creativity. [Further explanation and examples of evolutionary theory and astronomy for experiments] (Item 3)	evidences. If we do not learn these theories or law how can we understand their drawbacks? In order to enhance or support a theory we need to investigate it deeply and comprehend what it really says. (Item 6)	reach same conclusion and in that case scientific knowledge would not be improved. (Item 8)	protons. They need to use their creativity and make inferences by using relevant data. Scientists can be seem now so certain about this structure but this does not make this model hundred percent accurate. However there are no hundred percent truths in science. This model can change in accordance with new evidences or data. (Item 4)	creativity and also imagination. (Item 9)		society. And science is not universal. For instance in medicine application of embryonic stem is used but in some countries it is not allowed. It is regarded as unethical.

4	I Science helps us to explain that what we need to know in every area. This doesn't mean that it explains everything, but most of them. (Item 1) Doing experiment is the major role for scientific knowledge. (Item 3)	I Theories are not proven facts. [No accurate explanations] (Item 6)	II Every scientist has their own pre-knowledge and beliefs, these can affect the scientists' decision. This makes the different conclusions to occur. (Item 8)	I [No implication of emphasis for inference based on observation or experiment]	II They [scientists] use imagination and creativity after data collection. They regulate these data to plan and design a hypothesis or theory by using imagination and creativity. (Item 9)	I Theory tries to explain why something is true. Law describes something that seems true. (Item 5)	I Science is universal, because scientific theory does not change depending on where.
5	III Science depends on empirical data. Scientists do observations and inferences. (Items 1 & 3) But it is not always possible to do experiments or	II Theories can change after getting more knowledge and results. (Item 6) [Further explanation for the development of scientific	II Scientists have different conclusions because of their previous knowledge even if they have same set of data. (Items 8 & 7)	III Scientists are not sure of the structure of atom. They have model for it. (Interview follow-up) ...depend on observations,	III Scientists use their creativity in planning, and designing experiment and interpretation of them. (Item 9)	III Theories and laws are different. In some studies theories are formed after finding laws. (Item 5) A scientific law involves relationship; on the other hand, theories give	II Science develops under needs of society. Prior knowledge is affected from culture and society. (Item 10)

	observations. At these points, inferences emerge… (Interview follow up)	knowledge in Interview follow-up]		experiments and inferences, scientists reach the solution. ...they had evidences. (Item 4)		explanation for the phenomena. There is no hierarchy between them. (Interview follow up)	
6	III The content of science is determined (based) by observations and empirical data. ...it bases its inferences about natural phenomena in observation... In science we use experiments, models so that we can proof in a way the knowledge. (Item 1)	III Scientists tend to find the best explanation to a phenomenon and improve these explanations or relations or models as new evidence is found. (Item 1) If there is new evidence, or with the available evidence we come to a better	III Because the data interpretation is something that changes from scientist to scientist. It depends on their backgrounds, etc. And as these conclusions can not be based in evidence of experiments or direct observation there is more	III They don’t observe directly the atoms but indirectly they made quite a lot of observations. ...according to behaviors [of atomic and sub-atomic particles] and inferences that they made, they construct models. The atom may not	III ...they [scientists] use these [creativity and imagination] during the whole process. While constructing experiment, while observing, while interpreting data. [Further explanations and example] (Item 9)	III Law is a different kind of knowledge. There is no a hierarchy for their accuracy. (Interview follow-up) A scientific theory is the kind of scientific knowledge that explains how some phenomena occurs. A scientific law is the kind of scientific knowledge that gives relations between	III ...science tends (wants) to be universal but it is affected by cultural, social and political values, philosophical assumptions and intellectual norms of the culture in which it is ... ...as long as humans will be affected by these the science also will be

	[Experiments and observations] help us in making some inferences...(Item 2) Sometimes it is not possible to do experiments, in the space for example. As long as you interpret your data…in a logical way, it tells you…[about natural phenomena] (Interview follow-up)	explanation of the phenomena a theory is trying to explain, then the theory changes. We bother to learn scientific theories because they are the best explanations that we have until new one is developed if it is developed. (Item 5)	room for subjectivity and creativity of scientists. (Item 8)	look like the model but the model helps us to understand and predict the behavior of the atom. (Item 4)		phenomena in nature. [The big bang theory and the laws of motion] (Item 5)	affected. [Further explanation and example] (Item 10) You cannot get rid of you beliefs… (Interview follow-up)
7	II	II	I	II	III	III	III
	Science is empirically based....require experiments including collecting	...you can ask questions, and it [science] can change...with new scientific	[Used key terms - Background, theory laden and training program- But has no	...with new scientific evidences they [scientists] make inferences .[in	...scientists use their imagination and creativity... they set up experimental	Theory explains how a phenomena works...Law states relationships [with examples] (Item 5)	Science reflects social and cultural values. According to beliefs in a society, scientific

	data to develop.(Item 1 & 2) Scientists make inferences.(Item 4)	evidences. …atom theory has changed many times. (Item 1 & 6)	explanation.]	his further explanation, he has indication for prediction] (Item 4 & 6)	mechanism by themselves [indication for no single scientific method] (Item 4 & 9)		researchers are affected [Ex: evolutionary studies in Turkey] (Item 10)
8	III Science is the accumulation of knowledge in a developmental way by conducting experiments to understand how a natural event works. [ex: space; indication of inferences] (Item 1 & 2 & 3)	III Scientific knowledge is tentative. It can be refuted or improved by new data. They form a base; give a direction for our coming study areas. (Item 8)	III It is like to look at the same picture, but to see different things. Scientists may interpret the same data differently based on their study area, training, beliefs, previous knowledge, and culture. (Item 8)	III Scientists must speculate about what they can not see...they interpret their previous knowledge (Item 4 & 9)	III Scientists use imagination and creativity in situations that they can not observe and collect data. In every stage scientists may use imagination and creativity. (Item 9)	II Scientific theory gives explanations about how a phenomena works, but scientific law explains relationships in those phenomena. [ex: Mendel's law versus chromosome theory] (Item 5)	II Yes, it (social and cultural values) affects science. For example, in a Muslim country a Muslim scientist may not want to search evolution. (Item 10)
9	II It is the nature of	III Scientific	III It is subjectivity...	III Generating	III Constructing	III Theories are the	II Scientific

	science that makes it different from other disciplines of inquiry. In some scientific issues, it is impossible to make experiment; scientists make observations and some measurements. (Items 1 & 3)	knowledge is tentative. It is subject to change with the reinterpretations of the existing data or finding new evidences...(Item 6)	Generating scientific knowledge requires/involves human inference. Scientists’ background knowledge, expectations, values, attitudes influence their work and their interpretation of the data. (Item 8)	scientific knowledge requires/involves human inference. (Item 8) They benefit from their observations and recorded data. Their atom models are not the copies of reality. They construct scientific knowledge by using their creativity [implication for prediction] (Item 4)	scientific knowledge requires a great deal of human imagination and inference. It is in the every step of the scientific process starting from ...(Item 9)	explanations of the observed phenomena. Laws are the statements of relationships between concepts that explain how events/objects can be expected to behave or appear. [Extended with examples] (Item 5)	knowledge is socially and culturally based. [Ex: tsunami studies] (Item 10)
10	III	II	III	II	III	II	II

	Science is the knowledge about environment ...and nature and it depends on experiments and observation. Experiment is the set of things which is designed for exploring or observing change ...and it is not only for testing the hypothesis but also to see the changes in the known systems. [Further explanation and examples] (Items 1, 2 & 3)	Theories change because the scientists do many experiments about the theories and they find different things. Their findings are not only to develop the existing theory but also to refute it. (Item 6)	Since scientists have different backgrounds ...for example different trainings, religions, ideas, theories studied on ...they derive different conclusions while looking same set of data. (Item 8)	Scientists make experiments and get data from those experiments and they know same information ...they know that electrons *should* rotate around atom [nucleus]. And they are creative thus they can draw the picture of atom. (Item 4)	Scientists use imagination and creativity in all parts of scientific process. For example, when scientists found the bones of dinosaurs, they draw the figure of a dinosaur by looking a few bones. [Further explanation] (Item 9)	...scientists have these theories in order to give explanations for the laws. ...theories and laws are subject to change. (Item 5)	Science reflects social and cultural values because the scientists are affected by their culture. [Ex: evolutionary studies in Turkey vs. Islam] (Item 10)
11	II Science is a way of	III Because scientific	III Although	II With concrete	II In some scientific	III ...in scientific theory,	II ...scientific

	knowing and constructing unknown issues related with our life. [Nature] Nature of science ...makes science different from other disciplines. (Item 1)	knowledge is not absolute, it is tentative and subject to change with innovation/development in science. To understand and further investigations...(Item 6)	scientists get the same data in a research, they can conclude this data according to their background knowledge, beliefs, expectations and experiences. Therefore their conclusions may differentiate. (Item 8)	evidences, observations and inferences, scientists determine what an atom look like. (Item 4)	research, researchers use their creativity. Such as to determine the components of atom, although they can not observe through their eyes, they conclude their experiments with using their creativity. (Item 9)	the explanation about the scientific knowledge is given...But in scientific law the relationship is given. [Ex: Hook’s law] (Item 5)	researches depend on culture and social values... …scientific knowledge is socially and culturally embedded. (Item 10)
12	II Science is so different from other disciplines because it is based on experiments, it has evidences for natural phenomena... (Item	II Because scientific knowledge is not absolute. With time, with other researches, theories can be developed or changed. [we	III Because scientists are subjective. They can make different conclusions from the same set of data. This because of their	III They compose a model of atom. They make this by inferring. The model of atom can change in time. (Item 4)	II Yes. Actually in all of the investigations scientists use their imagination and creativity. (Item 9)	III Law is descriptions of phenomena. Theories are inferred explanations for observable phenomena. For example; Boyle’s law is about relationship	I Science is universal... (Item 10)

	1) ...on every area of science it is not possible to make experiments. [ex: astronomy] (Item 3)	learn theories] Because if we know them we can develop or change them... (Item 6)	educational background, environment etc. (Item 8)			about gas and its volume. Kinetic molecular theory explains Boyle's law. (Item 5)	
13	II Science is empirically based.(Item 9) To collect data about a topic, we do experiment, but not in all area. (Items 2 & 3) ..scientists make observation and inferences. (Item 4)	I Theories can change, because we use some of them to live easier or for technology. Theories are clues for new developments. (Item 6)	III Scientists reach different solutions from the same data because of the subjectivity of science. All scientists have different pre-knowledge, training and culture. All these factors affect their [scientists'] conclusions. (Item 8)	II Scientists make observation and inferences. ...they [scientists] infer different things from their experiments.(Item 9)	II Scientists use their imagination and creativity to make observation and inferences. For example parts of dinosaurs are given to different scientists, each one imagine different thing and give you different creature.(Item 4)	III Scientific theory gives explanations to the hypothesis. Scientific law gives relations to them. There is no scientific order or hierarchical order between them. (Item 5)	I Science is universal, because all scientists are in communication in the world. However, for some countries culture can affect the scientific knowledge. (Item 10)
14	II	II	III	II	III	III	III

	Science is based on facts...generally asks “why and how” questions. Scientific knowledge is based on observations and experiments. (Item 1)	..[scientific] knowledge tends to change with the new information . We can reorganize or reconstruct the theories. (Item 6)	Scientific knowledge is subjective. Scientists’ background, beliefs, experiments; values affect the scientific conclusions even if all scientists have the same data. (Item 8) Scientists interpret the data according to them. (Item 9)	..scientific knowledge is based on observations and inferences ...scientists interpret the data ...[prediction implication on dinosaur example in item 9]	Scientists use their imaginations in all steps. How they plan or design an experiment or a study, how they can collect data or where they can get the data and also while interpreting this data they use their imagination and creativity. [Ex: Dinosaur bones](Item 9)	Scientific theory and scientific law aren’t the same. Because scientific theory explains the fact while laws give definition about facts. There is no hierarchy between them. [Ex: Evolutionary Theory and Newton’s Law of Motion] (Item 5)	Social and cultural values form scientists’ characteristics. ...social and cultural values are the big part of their background. Even these values play role in determining the investigation of subject. (Item 10)
15	II Science is a thinking way, which helps us to determine and explain the	II Scientific theory gives the explanation of scientific phenomena. This	III Because of their creativity, they get different conclusions from the same data.	II Prediction and creativity is the basic causes of this... (Item 4)	II Scientists use their creativity when they do investigations. They use it when	III Scientific law is the relationship of two or more concepts, but scientific theory is the explanation of a	II Science is socially embedded. It is shaped according to society, norms of it etc. For example,

	universe... It is different from other disciplines of inquiry due to its provable explanations. (Item 1)	theory is not exactly true. If there is any exception, theory is broken. To get validity, theories should change. It means scientific theory may change, science is tentative, subject to change. (Item 6)	Moreover, both of the scientists have different prior knowledge, social values, norms, religions and ethical values etc. Because of these, they get different results from the same data. This means subjectivity, science is subjective... (Item 8)		planning and design and after data collection to determine unobservable issues. For example, evolutionary theory is not observable, so they use creativity to explain the theory. (Item 9)	concept. For example, Newton’s second law of force states that force is equal to the mass of the matter on which the force is exerted times acceleration of that matter. This is a scientific law. On the other hand, evolutionary theory is a scientific theory which explains the beginning of the life. (Item 5)	evolutionary theory totally disobeys the rule of Islam. Hence, there is very limited researches and studies about it [in Islamic countries] (Item 10)

APPENDIX J

TEZ FOTOKOPİ İZİN FORMU

ENSTİTÜ

Fen Bilimleri Enstitüsü [ ]

Sosyal Bilimler Enstitüsü [x]

Uygulamalı Matematik Enstitüsü [ ]

Enformatik Enstitüsü [ ]

Deniz Bilimleri Enstitüsü [ ]

YAZARIN

Soyadı : Baraz
Adı : Aytuğba
Bölümü : İlköğretim Fen ve Matematik Alanları Eğitimi Bölümü

TEZİN ADI (İngilizce) : The effect of using metacognitive strategies embedded in explicit-reflective nature of science instruction on the development of pre-service science teachers' understandings of nature of science.

TEZİN TÜRÜ : Yüksek Lisans [x] Doktora [ ]

1. Tezimin tamamı dünya çapında erişime açılsın ve kaynak gösterilmek şartıyla tezimin bir kısmı veya tamamının fotokopisi alınsın. [ ]
2. Tezimin tamamı yalnızca Orta Doğu Teknik Üniversitesi kullancılarının erişimine açılsın. (Bu seçenekle tezinizin fotokopisi ya da elektronik kopyası Kütüphane aracılığı ile ODTÜ dışına dağıtılmayacaktır.) [ ]
3. Tezim bir (1) yıl süreyle erişime kapalı olsun. (Bu seçenekle tezinizin fotokopisi ya da elektronik kopyası Kütüphane aracılığı ile ODTÜ dışına dağıtılmayacaktır.) [x]

Yazarın imzası .... Tarih ....