DEVELOPMENT OF PRE-SERVICE SCIENCE TEACHERS' NATURE OF SCIENCE VIEWS AND NATURE OF SCIENCE INSTRUCTIONAL PLANNING WITHIN A CONTEXTUALIZED EXPILICIT REFLECTIVE APPROACH

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To My Parents

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ABSTRACT

DEVELOPMENT of PRE-SERVICE SCIENCE TEACHERS' NATURE of SCIENCE VIEWS AND NATURE OF SCIENCE INSTRUCTIONAL PLANNING WITHIN A CONTEXTUALIZED EXPILICIT REFLECTIVE APPROACH

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The main focus of the study was to explore pre-service science teachers' understanding of NOS and translation of this understanding into their instructional planning for teaching NOS within the contextualized explicit reflective NOS based approach. The study, first investigated pre-service science teachers' development of NOS views as a result of explicit reflective NOS instruction in the context of HOS based science method course, which was designed to improve pre-service science teachers' both NOS views and NOS related instructional practices. Second, the present dissertation aimed to explore pre-service science teachers' trajectory progress of translation of NOS views into instructional planning. Seven volunteer pre-service science teachers were the participants of the study. An interpretive qualitative research was embodied as a research design for the current study. Data were collected by means of open ended questionnaire in conjunction with interviews, student journals and lesson plans and interviews. All of the participants achieved informed understanding almost for all NOS aspects. All participants achieved mostly informed views of NOS for various aspects at the end of the science methods course. None of the participants revealed inadequate understanding for any NOS issues at the end of the NOS intervention. Regarding development of NOS instructional planning, most of them provide NOS objectives, explicit reflective NOS instructional planning and some assessment strategies specific to NOS. Participants were attributed to their development for instructional planning NOS to several sources provided through the course. Mostly they perceived lesson plan presentations followed by discussions as main source contributing their NOS instructional planning.

Keywords: Nature of Science, Science Teacher Education, Nature of Science Teaching, Contextualized explicit reflective approach

ÖZ

FARKLI ÖĞRENME ORTAMLARIYLA İLİŞKİLENDİRİLMİŞ DOĞRUDAN YANSITICI YAKLAŞIMIN FEN BİLGİSİ OĞRETMEN ADAYLARININ BİLİMİN DOĞASI GÖRÜŞLERİ VE BİLİMİN DOĞASI ÖĞRETİM BECERİLERiNE ETKİSİNİN ARAŞTIRILMASI

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Bu çalışmanın amacı fen bilgisi öğretmen adaylarının bilimin doğası görüşlerini ve bilimin doğasını öğretime yönelik becerilerinin farklı öğrenme ortamlarıyla ilişkilendirilmiş öğretim yöntemleri dersinde geliştirilmesi ve ne tür faktörlerin bu gelişimine katıkı yapıldığının araştırılmasıdır. Bu çalışma özel öğretim yöntemleri dersinde gerçekleştirilmiştir. Toplam yedi fen bilgisi öğretmen adayı bu çalışmaya katılmıştır. Katılımcıalrın bilimin doğasına görüşlerindeki gelişimi incelemek için açık uçlu bilimin doğası görüşler anketi uygulanmıştır. Katılımcıların bilimin doğasını öğretme becerilerindeki gelişimi incelemek için ders planları ve yarı-yapılandırılmış görüşmeler ve yansıtıcı raporlardan faydalanılmıştır. Yine, katılımcıların bilimin doğası öğretimi becerilerine katkı yapan faktörleri araştırmak için yarı-yapılandırılmış görüşmelerden faydalanılmıştır. Analizler sonuçları, katılımcıların bilimin doğası ile ilgili görüşlerinde önemli ilerlemeler göstermiştir. Yapılan uygulama sonucunda katılımcıların hepsi görülerini, yeterli veya bilgili görüş kategorisine geliştirmiş, hiçbir katılımcının herhangi bir bilimin doğası boyutunda yetersiz görüşe sahip olmadığı gözlenmiştir. Genel olarak katılımcıların hepsi bilim doğası entegre edilmiş ders planlarında gelişim göstermiş ve bilimin doğasını açık ve yansıtıcı bir biçimde planlayabilmiştir. Başlangıçtaki ders planlarında, katılımcılar bilimin doğası ile ilgili kazanım yazmakta ve bu kazanımları etkinlikler aracılığıyla yansıtmakta zorluk çekmişlerdir. Fakat son ders planları göstermiştir ki uygulama süresince katılımcılara verilen geri-dönüt, bilim tarihinden sağlanan örnekler, ders planlarının mikro

öğretim yoluyla sunulması, katılımcıların gelişimine önemli katkılar yapmıştır. Buna göre katılımcılar uygulama sonrasında birçok boyut için açık ve yansıtıcı olarak planlama yapabilmişlerdir. Sonuç olarak, bu uygulamada kullanılan farklı öğrenme ortamlarıyla ilişkilendirilmiş açık yansıtıcı bilimin doğası yaklaşımının, geri-dönüt, yansıtıcı etkinlikler, mikro-öğretim, ders planı hazırlama gibi etkinliklerle zenginleştirilmesiyle etkinliği artmış ve katılımcıların bilimin doğası görüşlerinin gelişimi ve bilimin doğası ile ilgili ders planlama becerilerine olumlu katkıları olmuştur.

Anahtar kelimeler: Bilimin doğası, Bilimin doğası öğretimi becerileri, İlişkilendirilmiş doğrudan-yansıtıcı yaklaşım, Öğretmen eğitimi

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NOS: Nature of Science

PCK: pedagogical Content Knowledge

AAAS: American Association Advacement for Science

PST: Pre-service Science Teachers

HOS: History of science

VOST: Views of Science, Technology, Society

VNOS-C: Views of Nature of Science Questionnaire, Form C

CHAPTER 1

INTRODUCTION

The need for enhancing society as scientifically literate is regarded as vital goal in many countries. Scientifically literate person is defined by American association for the advancement of Science (AAAS,2001), as someone that is familiar with the natural world, understands some key concepts of science, be able to think in a scientific way, aware of interdisciplinary nature of science, appreciates science mathematics and technology are human enterprise which implies strengths and weaknesses of science, and able to use scientific knowledge and ways of thinking for personal and social issues. Thus, science education aims to increase scientific literacy which leads to improve in scientifically literate adults in society resulting in improvement of public understanding of science. Driver, Leach, Millar, and Scott (1996) suggest that public understanding of science involves three stages. First stage is related to understanding of science content. It includes understanding of facts, laws, theories which are consisting of scientific knowledge. Second stage is related to an understanding of the scientific approach to enquiry. It involves ability to define scientific study, distinguish science from non- science. Moreover, this aspect of science understanding recognizes the role of theoretical and conceptual ideas in framing any empirical enquiry and interpreting the outcomes as well as the understanding of empirical enquiry procedures. Last stage refers to understanding of science as a social enterprise which refers to understanding of science in society and society in science. That stage is related with knowledge about science rather than natural world. It involves understanding of the social organization of science, its mechanism for checking, receiving, and validating knowledge and it also includes recognizing of influence of society and values on scientists choices and interpretations.

It was claimed that reaching the goal of totally scientific literate people could be achieved by in science courses if students were taught about nature of science (NOS). Thus understanding of nature of science (NOS) is the indispensable part of scientific literacy (Abd-

El-Khalick & Lederman, 2000). Despite of the crucial importance of NOS understanding to achieve scientific literacy, there is no agreement on the meaning of NOS. Generally, Lederman (1992) defined NOS as values and assumptions inherent to development of scientific knowledge. Scientific knowledge has been introduced seven agreed characteristics (Abd-El-Khalick, Bell, & Lederman, 1998; Akerson, Abd-El-Khalick, Lederman, 2000) which were are not a compliment list but rather presented as a framework to describe NOS aside from scientific inquiry. These tenets also described what constitutes NOS in the present dissertation. The first tenet is empirical nature of scientific knowledge. This tenet states that science is based on and derived from observations and experiments. Scientists need empirical evidence to produce scientific knowledge. Scientists evaluate accuracy of their claims based on the evidence acquired with data through observations and experiments. Moreover, not all kind of scientific knowledge is constructed solely based on experiments; observations are as equal scientific method to reach scientific information. The second one is the tentative nature of scientific knowledge. It refers that scientific knowledge is subject to change in the light of new evidence through advances in technology or theory, reinterpretation of existing knowledge or new perspective. Although scientific knowledge is reliable and durable, it is not concrete or perfect. That is, scientific knowledge is never absolute or certain. All kind of scientific knowledge including facts, theories and laws are tentative. The third tenet is related to the scientific knowledge that based on inferences and observations as well. This tenet highlighted that there is a crucial distinction between observation and inference. Observations are descriptive statements related to phenomena gathered through using senses. Scientific knowledge is not acquired through accumulation of observable evidence. In that sense, inferences are the interpretations of observations. Scientists' imagination, creativity, background and perspective do contributions on how scientists interpret observations. Scientists might infer models, or mechanism to explain observations in nature (e.g. evolution, atom models). Another tenet was related to the theories and laws. It explains scientific theories and laws as a different kind of scientific knowledge. There is no hierarchical relationship between theories and laws. Scientific laws are the description of observed phenomena or statements about the perceived relationships, patterns or regularities in nature (e.g. Boyle's law relating pressure of a gas to its volume at a constant temperature). Theories are the inferred explanations for observable phenomena (e.g. kinetic molecular theory provides explanation for what observed and described in Boyle's Law).The fifth tenet is the subjective nature of scientific knowledge. It explains although scientists look for objectivity while doing scientific investigations, it is inevitable that scientists do scientific investigations, observations, inferences without any bias. That is, scientists' theoretical commitments, personal values, prior experiences, expectations and background influence what and how scientists conduct their research. Contrary to common sense, scientists' do begin observations and investigations with mind-set questions, problems, derived from certain theoretical perspective. The sixth tenet is the creative and imaginative nature of scientific knowledge. It points out that scientific knowledge partially involves scientists' imagination and creativity. It is not solely based on or derived from observations of the natural world. Scientists use their imagination and creativity while designing experiments, hypothesizing, collecting data, analysis, and making sense of data. Additionally, scientists use their imagination and creativity to fulfil missing information as well. The last tenet is related to socio-cultural emdeddedness of scientific knowledge. It outscores that scientific knowledge is produced within a culture and society in which scientists belong to. Thus, socio-cultural components like politics, economics, power structures, religion, values of society, philosophy are influential on how and what scientific knowledge is produced and also its acceptance within the social community of culture.

Understanding of NOS is defined as understanding of what science is and how it works, interaction between science and society, and epistemological and ontological underpinnings of science (Clough, 2006; McComas, 1998). An appropriate understanding of NOS which is accessible to K-12 students, includes recognition of purpose of science as seeking for explanations in natural world, identifying role of science as social institutions and appreciation of interaction between science and culture as well as understanding the nature and status of scientific knowledge (Driver, Leach, Millar, & Scott, 1996; Lederman & Abd-El-Khalick, 2000; McComas, 1998). Driver et al. (1996) provided some arguments on why the development of appropriate understanding of NOS was essential in science education: Understanding of NOS is necessary to make sense of science and manage technology in daily life; informed decision making on socio scientific issues requires appropriate understanding of NOS; appreciation of science as a part of contemporary culture and recognition of the influence of scientific norms on moral commitments demands understanding of NOS. Lastly they claimed that it facilitates better science subject learning. In the same vein, Ryder et al. (1999) stated that views on nature of scientific knowledge affects the development of students' scientific concepts. Moreover, they claimed that appropriate understanding of nature of scientific knowledge leads to more informed.

Even though nature of science understanding has been claimed to be an important learning outcome for science education approximately for 100 years, research studies have consistently shown that both students (Abd-El Khalick & Lederman, 2000; Akerson, Nargung-Johsi, Weiland, Pongsanon, & Avsar, 2013; Dogan & Abd-El-Khalick, 2008) and teachers have naïve ideas and nature of scientific knowledge (Abd-El-Khalick, 2005; Akerson & Abd-El-Khalick, 2000; Cil & Cepni, 2012; Akerson & Donnely, 2010; Ozgelen, Tuzun, & Hanuscin, 2012). These naïve views of both students and teachers were more likely to be result of experiences from their science education. Eventually, typical science instruction having lack of focus on the values and assumptions inherent to the development of scientific knowledge were more likely to contribute to the development of naïve views of nature of science (Bell, 2004).

Both teachers' and students' naïve NOS views lead researchers to take attempts to improve NOS views. The research investigations attempted to change naïve conceptions on NOS took two approaches-implicit and explicit approaches. Implicit NOS instruction refers to understanding of NOS as a learning outcome that could be attained through process of skill instruction, science content course work and doing science (Lederman, 2007). Learning of NOS was perceived as by-product of learners' engagement with science-based activities. Science teachers or educators intending to use implicit approaches assume that NOS could be taught through focusing on science processes or constructivist activities. That is, implicit approach views NOS as an affective outcome claiming NOS views to be more attitudinal in nature (Abd-El-Khalick & Lederman, 2000). On the other hand, explicit approach to nature of science instruction is the philosophy that treated teaching as purposive and goal-driven (Bell, 2004). Schwartz, Bell and Lederman (2004) stated that "the explicit approach advances that improving views of NOS should be planned for through objectives, instructional attention, and assessments. This approach intentionally draws learners' attention to aspects of NOS through discussions, guided reflection and specific questioning in the context of activities, investigations, and historical examples"(p. 614). According to Abd-El-Khalick and Lederman (2000), explicit approach has assumed that NOS views could be enhanced by instructional prompts targeting NOS aspects as explicit instructional outcomes which are compatible with instructional objectives and assessments. Later, Abd-El-Khalick (2005, 2012) pointed out explicit approach as consisting of explicit component and reflective component. He linked explicit component with curricular implications and he noted that: "...far from referring to direct or other modes of didactic instruction, the label explicit emphasizes the need for including specific NOS learning outcomes in any instructional sequence aimed at promoting NOS understanding" (p.1057).He emphasized reflective component as a part of explicit approach as paying attention to how the activities illustrate NOS aspects and how students' own inquiries and scientists were similar or different where explicit instruction of NOS focuses key aspects of NOS through discussions and written work following by engagement of hands-on activities (Abd-El-Khalick, 2005, 2012). Additionally, Abd-El-Khalick (2012) explained reflective label of an explicit reflective NOS instruction as:

> The reflective component nonetheless does entail instructional elements to be incorporated into pedagogical approaches. There is a need for the provision of the structured opportunities designed to encourage learners to examine their science learning experiences from within a NOS framework. The latter framework would focus on questions related to the development and validation of, as well as the characteristics of, scientific knowledge…this reflective component had often taken the form of questions or prompts embedded within science learning activities…" (p. 1057).

Recent review of empirical studies on improving science teachers' understanding of NOS concluded that explicit reflective approach was generally more effective in enhancing appropriate conceptions on NOS (Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002; Abd-El-Khalick, 2005). Lately, explicit reflective approach found to be more effective if it was undertaken through contextualized settings such as history of science (Clough, 2006; Abd-El-Khalick, 2005; Kim & Irving, 2010; Rudge & Howe, 2009; Lin & Chen, 2002), inquiry based context (Khisfe & Abd-El-Khalick, 2002; Schwarzt, Lederman, & Crawford, 2004; Schwarzt & Crawford, 2004; Yacoubian & BouJaoude, 2010), and learning as a conceptual change (Abd-El-Khalick & Akerson, 2004).

Regarding transition of NOS views into science teaching, science teachers' naïve understanding of NOS has been crucial factor keeping them emphasizing NOS explicitly and reflectively which also lead students acquiring undesired NOS views (Lederman, 1992; Akerson, Buzelli, & Donnely, 2008; Abd-El-Khalick & Akerson, 2004; Dogan, Cakiroglu, Cavus, Bilican, & Arslan, 2011). Although teachers' understanding of NOS was essential to include NOS into their practice, it did not guarantee translation of their understanding into science teaching (Lederman, 1999; Bell, Matkins, & Gansneder, 2011; Akerson & Volrich, 2006; Demirdogen, 2012). Previous studies have pointed out that even science teachers had informed NOS views and intention to teach NOS, they still could not achieve explicit reflective NOS instruction (Akerson & Abd-El-Khalick, 2003). Literature has implied that science teachers need help particularly on learning how to teach NOS. Accordingly, Lederman (2007) argued that teachers needed to develop sort of PCK (Gess-Newsome, 1999; Shulman, 1986) which was specific to NOS to be able to address NOS in their science teaching in addition to deep understanding of NOS. Abd-El-Khalick and Lederman (2000) noted that PCK for teaching NOS included "…..an adequate understanding of various aspects of NOS, knowledge of a wide range related examples, activities illustrations, explanations, demonstrations, and historical episodes. These components would enable the teachers to organize, represent, and present the topic for instruction in a manner that makes target aspects of NOS accessible to precollege students. Moreover, knowledge of alternative ways of representing aspects of NOS would enable the teacher to adopt those aspects to diverse interests and abilities of learners (Abd-El-Khalick, & Lederman, 2000). In other words, PCK for NOS was reported as knowledge of science teacher that makes targeted NOS aspects attainable by students (Lederman, 2007). Research suggested scaffolds, continuous support, feedback and NOS modelled lessons to improve PCK for NOS. It was concluded that these kinds of supports enable teachers to translate their NOS understandings into their teaching effectively (Akerson, Cullen, & Hanson, 2009; Akerson & Volrich, 2006; Akerson & Abd-El-Khalick, 2003). Moreover, these studies have urged that efforts needed to help teachers to shift their pedagogical approach toward teaching NOS explicitly and reflectively, learn assessing students' NOS understandings and develop abilities to integrate NOS into science content. Therefore, the question of how to develop science teachers' knowledge in NOS instruction is still to open investigation (Kim, Ko, Lederman, & Lederman, 2005; Lederman, 2007).

Discussions above indicated that to help science teachers to effectively address NOS, there is a need to improve their NOS understanding and their knowledge in NOS instruction and further explore the learning experiences contributing translation of their NOS conceptions into practice. Such is the purpose of the present dissertation which was undertaken with pre-service science teachers in research intense public university within a science methods course. In order to improve pre-service science teachers' understanding of NOS, the present study included explicit reflective framework enriched with history of science examples. History of science provided some sort of context coupled with explicit reflective NOS obtaining more effective explicit reflective approach (Abd-El-Khalick, 2005; Clough, 2006). Additionally, participants were provided opportunities to be aware of their initial NOS concepts revise their concepts and reflect on their relative status of these concepts (Abd-El-Khalick & Akerson, 2004; Bilican, Cakiroglu, & Tekkaya, 2012; Dogan, Cakiroglu, Bilican & Cavus, 2013). Moreover, NOS intervention was embedded in learning science content in which participants focused on instructional objectives form national science curricula, and modified curricula to integrate NOS which could be enacted in their own classrooms. Additionally, they were provided with opportunities and support to design their own NOS lesson plans and assessments. That component of the intervention provided content-rich context for addressing NOS issues utilizing effective explicit reflective NOS instruction (Bilican, Cakiroglu, & Tekkaya, 2012; Wahbeh, 2009).

Regarding developing knowledge in NOS instruction which facilitates translation of NOS views into practice, some elements of intervention played an important role. These elements included reflective discussions, feedback, modelling the teaching about NOS by participants and designing NOS lesson plans. These latter elements contributed to development of PCK for NOS through designing lesson plans including demonstrations, explanations, HOS examples, and illustrations targeting NOS aspects as well as NOS assessments. While designing lesson plans, participants were supposed to prepare their lesson plans in the context of HOS as well as science content. They were required to integrate some elements of HOS (e.g. historical development of science concepts, life of scientists) while planning to teach particular science content as well as integrate NOS. Therefore, in current study, HOS was expected to improve their NOS understanding as well as their NOS instructional planning in addition to the former elements. Additionally, regarding development of PCK for NOS, the intervention aimed to enable pre-service science teachers to learn about NOS aspects and general pedagogies related to NOS through content generic activities, examples from history of science and design of lesson plans to teach NOS in the context of different science contents. Major elements in the current study were NOS lesson plan creation and presentations followed by discussions which provided them with a form of reflective practice and giving feedback to pre-service science teachers NOS lesson plans. In sum, pre service science teachers were provided with structured opportunities enabling them thinking, revising and modifying their own NOS teaching by means of lesson plan creation which contributed to development of PCK for teaching NOS (Abd-El-Khalick, 2005; Gess-Newsome, 1999). Next, purpose of the present dissertation was provided.

Purpose of the study

The main focus of the study was to explore pre-service science teachers' understanding of NOS and translation of this understanding into their instructional planning for teaching NOS within the explicit reflective HOS based approach. The study, first investigated pre-service science teachers' development of NOS views as a result of explicit reflective NOS instruction in the context of HOS based science methods course designed to improve pre-service science teachers' both NOS views and NOS related instructional practices; second explored pre-service science teachers' trajectory progress of translation of NOS views into instructional planning and third, explored learning experiences contributed to pre-service science teachers' ability to design NOS lesson plans. Research questions leading the study were as following:

I. How do pre-service science teachers' NOS understandings change in the contextualized explicit reflective approach?
II. How is the progress trajectory of pre-service science teachers in relation to integrating NOS into their lesson plans as a result of feedback in the contextextualized explicit reflective approach?
III. What learning experiences do contribute to pre-service science teachers' ability to integrate NOS into their instructional plans?

Significance of the study

Scientific literacy has been stated as perennial goal of science education by both national and international science education documents. NOS has been indispensable component of scientific literacy. Therefore, having students with desired understanding of NOS is one of the main attainments to achieve scientific literacy. However, many studies have reported both pre- and in-service science teachers' lack of understanding of nature of science (Akerson & Abd-El-Khalick, 2005; Lederman, 2007; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) which have resulted in their avoidance of addressing NOS in their instruction. Accordingly, such reluctance prevents students developing informed ideas on nature of science (Abd-El-Khalick & Akerson, 2009; Abd-El-Khalick & Lederman, 2000; Bell, Matkins, & Gansneder, 2011; Lotter, Singer, & Godley, 2009; Seung, Bryan, & Butler, 2009). Thus, science teacher education programs should help pre-service science teachers gain more improved NOS ideas. Consequently, pre-service teachers would be skilled enough to help their own students gain adequate views of nature of science.

Although, the research focused on improving science teachers' NOS views within mostly science methods course reported some success, the effect was is short term. (Akerson & Morrison, 2006). Limited success in facilitating pre-service science teachers' conceptions of NOS is stated due to non-contextualized approach of explicit reflective NOS instruction within the science methods course (Bell, Matkin, & Gansneder, 2011; Matkins, Bell, Irving & McNall, 2002; Schwartz, Lederman, Khishfe, Lederman & Liu, 2002). Non contextual approach leads pre-service science teachers believe that "real science" works differently from what they have taught (Clough, 2006). Therefore, it might be stated that contextualized explicit reflective NOS instruction is more effective in facilitating pre-service science teachers to have contemporary conceptions of NOS (Abd-El-Khalick, 2002; Seung, Bryan & Butler, 2009). For example, History of Science is claimed to be an effective way to contextualize NOS instruction because historical examples related to science serve as a specific reference to NOS tenets (Abd-El-Khalick, 2001; Abd-El-Khalick & Lederman, 2000), and provide learners with opportunities not only to learn issues relating to NOS but also science content (Paraskevopoulou & Koliopoulos, 2011). However, to our knowledge, there are only few studies regarding effectiveness of HOS contextualized explicit reflective NOS instruction on improving pre-service science teachers' NOS views (Bell, Matkins & Gansneder, 2011; Seung, Bryan, & Butler, 2009). Thus, current study has aimed to fill the gap in the literature by exploring development of NOS views of pre-service science teachers in a contextualized science methods course by means of incorporation of history of science based explicit reflective NOS instruction.

The development of NOS views of pre-service science teachers is important because the national and nationwide reform documents related to science education hold science teachers responsible for addressing NOS in their practice regardless teaching experience (American Association for the Advancement of Science, 2001; National Science Education Standards, 1996, 2000; National Turkish Ministry of Education, 2004). On the other hand, research has revealed that adequate understanding of NOS does not guarantee translation of these concepts into instructional practices (Abd-El-Khalick & Lederman, 2000; Bell, Matkins & Gansneder, 2011). Therefore, in addition to having appropriate understanding of NOS, teachers also should possess necessary skill to translate this knowledge into their instructional practices which requires ability to either adapt or design NOS integrated science lessons. Nevertheless, teachers are not experienced in designing and teaching NOS integrated science lessons effectively (Bell, Matkins, & Gansneder, 2011). Therefore, first of all, we should help pre-service teachers gain the necessary knowledge and practice of adapting and designing NOS lessons. Beyer and Davis (2009) argued that teachers' practice of designing lessons is closely related to their pedagogical design capacity. It includes use of personal resources and curriculum to make feasible adaptations to curricula to design powerful learning opportunities for students' learning (Hanuscin, Lui, & Akerson, 2011). It is obvious that pre-service teachers need support in developing their pedagogical design capacity for teaching NOS. Adopting pedagogical design capacity for NOS teaching is a new standpoint has not been explored yet. Critique and adaptation of existing curricular materials is believed to be an authentic task of teaching and improve their pedagogical design capacity (Beyer & Davis, 2009; 2012; Davis, 2006). Furthermore, it is claimed that pre-service science teachers should embrace NOS standpoint as a criteria for critiquing and adapting instructional materials (Beyer & Davis, 2009; Davis, 2006; 2012; Lederman, 1992). Thus, pre service science teachers need to learn how to adapt curricular material to meet their instructional goals and their students' needs to address NOS effectively in their practice. However, literature has lack of studies exploring development of pre-service science teachers' existing curriculum adaptation for NOS teaching. Therefore, current study has aimed to shed light on how pre-service teachers' critique and adaptation existing curricula for NOS teaching as a result of provided feedback while designing NOS lessons based on the pre-determined Turkish science curricula content.

Apart from having adequate understanding of NOS and pedagogical design capacity for teaching NOS, pedagogical content knowledge (PCK) for NOS is also required for the ability to teach NOS (Abd-El-Khalick, & Lederman, 2000; Aydin, Demirdogen, Muslu, & Hanuscin, 2013; Wahbeh & Abd-El-Khalick, 2013;). Although, both in-service and pre-service science teachers need to have certain level of PCK for NOS to be able to include it in their instruction (Abd-El-Khalick, 2005; Demirdogen, 2012), still there is much left to be explored regarding pre-service science teachers' PCK for NOS (Akerson & Hanuscin, 2007; Demirdogen, 2012; Hanuscin, Lee & Akerson, 2011; Lederman, 2007). Given the fact that PCK improves during teaching experience, it is hard to make robust claims regarding pre-service science teachers' PCK for NOS due to limited science teaching experiences. However, there could be opportunities for pre-service teachers to gain this experience other than teaching. For example, NOS integrated lesson plan preparation might be a good indicator for trajectory of PCK for NOS (Bilican, Tekkaya, & Cakiroglu, 2011). Some researchers claimed that lesson plan preparation allows researchers to gain insights of PCK of both in-service and pre-service teachers (Jacobs, Martin, & Otieno, 2008; Mutton, Hazel & Burn, 2011; Rusznyak & Walton, 2011). In general, developing lesson plans provides teachers with opportunities regarding to think deeply on subject matter knowledge represented in textbooks, and curriculum standards. Additionally, it requires teachers to create or utilize pedagogical activities or instructional strategies enabling students grasp the subject matter best. In that sense, NOS integrated lesson planning is expected to provide teachers with genesis of pedagogical content knowledge regarding NOS (Abd-El-Khalick, 2005; Panasuk & Todd, 2005) such as having NOS specific instructional and assessment strategies. Despite the potential use of NOS integrated lesson plans to explore and improve PCK for NOS, such lesson plan preparation of pre-service science teachers' has not been paid attention systematically within the PCK theory lenses. Therefore, it is necessary to investigate development of pre-service science teachers NOS integrated lesson plans to gain insights on their PCK for NOS, and better help pre-service science teachers to improve their abilities to teach NOS. However, there is a lack of studies assessing lesson plans to shed light on development of various dimensions of PCK for NOS. For instance, how pre-service teachers perceive and translate explicit and reflective component of NOS teaching into their instructional planning as a result of various kinds of support, might shed light on dimensions of PCK such as knowledge of instructional strategies. Additionally, lesson plans give idea on how pre-service science teachers plan to assess students' understanding of NOS which is related knowledge of assessment dimension of PCK (Magnusson, Krajcik, & Borko, 1999). Thus current study has been unique in terms of utilizing systematic track on pre-service science teachers' NOS integrated lesson plans in terms of exploration various components of PCK for NOS. In addition to these, current study fills the gap in literature by introducing a different way of projecting some components of PCK for NOS that is NOS integrated lesson planning. Additionally, teachers' orientation to teaching of NOS has been also addressed as another component of PCK (Friedrichsen, Driel, & Abell, 2011) for NOS in current study by HOS contextualized NOS instruction. In the literature, it is indicated that pre-service teachers are required contextualized models of NOS instruction to consolidate their instruction (Akerson, Morrison, & McDuffie, 2006; Lederman, 2007), which eventually will increase their orientation to teaching NOS. That is, contextualized NOS instruction by means of HOS in the current study leads pre-service teachers think NOS as an integral part of their science instruction rather than an addition on part to their teaching. Therefore, this study has been important to conduct to show how development in pre-service teachers' perception of teaching NOS as an integral part of their science instruction could be promoted by history of science (HOS) contextualized science methods course.

Consequently, current study has been unique regarding several points such as informing about impact of history of science contextualized explicit reflective NOS instruction on pre-service science teachers' understanding of NOS, investigating their ability to design explicit reflective NOS integrated lessons and informing the audience regarding development of some components of PCK for NOS. The current study aims to contribute knowledge on effective NOS instruction strategies and pre-service science teachers' NOS related instructional practices.

CHAPTER 2

LITERATURE REVIEW

The purpose of the study was to investigate pre-service science teachers' development of NOS understanding and development of translation of NOS understanding into instructional planning. Therefore, overview of students, in-service and pre-service teachers' NOS understanding, strategies to improve NOS understanding and factors impeding translation of NOS understanding into practice are reviewed in this chapter. Firstly, empirical studies related to students' NOS understanding were presented below.

2.1. Students' nature of science understanding

NOS understanding have been argued to enhance students' attitudes towards science, lead informed decision making and facilitate science content learning (Driver et al., 1996). Accordingly, the development of students' NOS understanding has been considered vital part of science instruction. However, vast majority of research indicated inadequate views of students ranging from early grades level to middle and secondary grade level (Akerson, Nargund-Joshi, Weiland, Pongnason, & Avsar, 2013; Akerson, Buck, Donnelly, Nargund-Joshi, & Weiland, 2011; Akerson, Donnely, 2010; Cil & Cepni, 2012; Dogan & Abd-El-Khalick, 2008; Khisfe & Abd-El-Khalick, 2002; Kilinc, Sungur, Cakiroglu, & Tekkaya, 2005; Yenice & Saydam, 2010; Walls, 2012).

In this part, five empirical researches which were conducted with varying elementary level have been reviewed through historical order. Through the review of the studies related to students' NOS views, the empirical research conducted with students at elementary level were chosen, due to the fact that the focus of the present study was pre-service elementary science teachers who will teach science in elementary level in future. First study was conducted by Kang, Schaoksalrmann, and Noh (2005), in Korea. They explored 1702 Korean 6th, 8th, and 10th grade students NOS views. In this study, students' views on the nature of science (NOS) were investigated with the use of a large-scale survey which was a multiple-choice format questionnaire. The questionnaire consisted of five items which examined students' views on purpose of science, definition of scientific theory, nature of models, tentativeness of scientific theory, and origin of scientific theory. Researchers reported no significant difference related to NOS views regarding grade level. Results showed that majority students possessed absolutist/empiricist perspective about the NOS. That is, the vast majority of the students held the view that "scientific theories are facts which have been proven by experiments". Around half of the students believed that models are proved by experiments. It was found that only few students (6th graders: 3.3%, 8th graders: 2.4% and 10th graders: 1.1%) revealed adequate understanding of tentativeness of scientific theories. Nearly %50 of the students regardless grade level possessed the belief that scientists discover theories as they already exist as objects. Researchers concluded that findings of the study called for emergent efforts for the design of science lessons, units and curricula which facilitated better NOS views.

In the same year Akerson and Abd-El-Khalick (2005) investigated younger elementary students' NOS views by means of qualitative methodology in USA this time. The authors explored 23 fourth grade elementary students' NOS views by using open-ended questionnaire (VNOS-B) coupled with one to one interviews. Particularly, students' NOS views regarding the distinction between observation and inference, creative NOS views, and tentative NOS views had been sought for. The open-ended questionnaire (VNOS-B) was modified by adding a content specific item targeting views of observation and inference in the context of content that students were studying in the class. The analysis of VNOS-B and interviews of the study showed that most of the students (N=22) demonstrated inadequate views on the NOS aspects which were concern of the study. For instance, 21 students showed inadequate views of creativity and imagination in science. They did not believe that scientists' imagination and creativity was influential in scientific work. Regarding tentative NOS, most of the students' conception of change in science was as only "adding on" new information to science. That is, they did not think of role of new interpretations, new perspective or role of new evidence. Related to observation and inference, most of the students (N=21) revealed contradictory views of the relationship between observation and inference. They generally believe that scientists look at evidence and get all the answers directly. Only two of them recognized the role of evidence to make inferences. In sum, the researchers of the study asserted that fourth grade student's NOS views were not aligned with the recommendations of the educational reform documents. They recommended that teachers needed to first know their students' NOS views and then plan explicit reflective NOS instruction to help them improve their NOS views.

Three years later, a similar study was undertaken with elder students in US (Khisfe, 2008). As a part of larger study exploring development of seventh graders NOS views, the researcher examined 18 seventh grade students' NOS views. Data were collected by means of open-ended questionnaire in conjunction with semi structured interviews. The questionnaire consisted of four items in which two of them were content embedded and two of them content generic questions. All items were designed to assess participants' NOS views related to tentative, empirical, creative NOS as well as the distinction between observation and inference. Analysis of open-ended questionnaire indicated students' naive ideas on targeted NOS aspects. For instance, regarding tentative NOS, majority of the students (72%) believed that "knowing is seeing". Similarly, vast majority of students (82%) failed to differentiate observation and inference. Related to empirical and creative NOS nearly half of the students revealed naive views. They could not appreciate the role of evidence. They failed to recognize the notion that scientific knowledge can be produced through indirect evidences. Moreover, they did not appreciate the role of imagination and creativity in development of scientific knowledge. Researcher recommended that the current study presented an initial step to explore NOS views of students and students' NOS views could be improved through effective NOS instructional strategies.

Attempts have been taken to explore elementary grade students NOS views in Turkish context as well. Last two studies reviewed in the current section were investigated Turkish eight graders and seventh graders' NOS views. For example, Yenice and Saglam (2010) examined 187 eight grades NOS views by means of quantitative methods. They used Nature of Science Knowledge Scale (NSKS) to determine eighth graders' NOS views. The NSKS scale was a 5-likert scale ranging from strongly agree to strongly agree with 16 items. The scale covered three tenets of nature of scientific knowledge which were characterized as "scientific knowledge is closed", "scientific knowledge is justified", and "scientific knowledge may change". The analysis revealed that students generally were unsatisfactory on the nature of scientific knowledge. They believed that science was certain and authority based but at the same time science could be empirically tested. Moreover, the analysis indicated that they did not view science as tentative. The researchers concluded that Turkish eight graders held inadequate view of science. Their recommendation was to plan science lessons in a way that help students to overcome their misconceptions regarding nature of science.

After two years, Cil and Cepni (2012) yielded similar results working with Turkish seventh graders. They investigated 22 seventh grade students NOS views as a part of larger study aiming to develop NOS views. An open-ended questionnaire follow up by with semi-structured interviews was used to explore seventh grade students' NOS views. Researchers reported seventh graders NOS views mostly as transitional for most of the aspects before explicit reflective NOS instruction. That is, majority of the students could not reveal complimentary view on tentative, creative, and empirical NOS. Moreover, vast majority of them could not differentiate inferences and observations. Researchers concluded that current science education did not help students gain contemporary view of science. They made calls for designing effective instructional strategies to help students gain desired NOS understanding.

To sum up, empirical research concluded that elementary level students held inadequate NOS views. However, it was claimed that both pre-service and in-service teachers can develop teaching strategies which resulted in favourable changes in students' NOS views (Akerson & Hanuscin, 2007; Akerson & Volrich, 2006; Akerson, Abd-El-Khalick, & Lederman, 2000). Undeniably, for having students' with more desirable NOS, teachers' understanding of NOS should be aligned with current education documents. Therefore, exploring NOS views of both pre-service and in-service science teachers' NOS views would be an initial step to help elementary level students develop more appropriate NOS views. Following section provided research from literature related to pre-service and in-service science teachers' understanding of NOS.

2.2. Pre-service and in-service science teachers' NOS understanding

Under this heading, empirical studies related to pre-service and in-service science teachers' NOS views undertaken in variety of culture were presented through a historical order. Through the current section, studies compared both pre-service and in-service science teachers' NOS views were provided as well as the studies only focused on either pre-service or in-service science teachers' NOS views in a historic sequence. Finally, empirical research which concerned pre-service and in-service science teachers NOS views in Turkish context were presented at the end of the present section. The empirical studies which were chosen for the review in current section included the wide range of studies undertaken by means of either qualitative or quantitative methods, with both pre-service and in-service science teachers, and with larger and smaller samples. All the review of these studies were aimed to provide a framework related to both pre-and in-service science teachers NOS views in international and national level. The first study reviewed was work of Haidar (1999), conducted in United emirates. Haidar (1999) investigated 31 pre-service science teachers' and 224 in-service science teachers' NOS views. He administered five-dimensional scale survey which was prepared by the researcher by utilizing items from various NOS scales. The scale included questions related to theories and models; role of scientists; scientific knowledge; scientific method; and scientific laws. Both pre-service and in-service science teachers were asked questions reflecting various points of science views (e.g. traditional views, constructivists' views). Approximately, half of the participants revealed the recognition that scientists' preconceptions, background, theoretical perspectives played role in development of scientific knowledge. That is, half of the pre -service science teachers in the study recognized science as a social construct. Additionally, around half of the participants stated that scientist should follow the steps of scientific method. Regarding tentative nature of scientific knowledge, 48% of pre-service science teachers and 68% of in-service science teachers pointed out that science is cumulative. Haidar concluded that both pre-service and in-service science teachers held mixed views of science. He suggested that introducing science from a constructivist point of view would help teachers to develop more desirable NOS views.

Two years later, Tairab (2001) conducted another study to explore both pre-service and in-service science teachers' NOS views in Buhrein. The sample of the study was 42 pre-service science teachers and 54 in-service science teachers. Particularly, the study explored participants' views on the characteristics of science and technology, the aim of science and scientific research, the characteristics of scientific knowledge and scientific theories, and the relationship between science and technology. Data were collected by means of 26-itemed Nature of Science and Technology Questionnaire (NSTQ) measuring various aspects of NOS. The findings revealed that both pre-service and in-service science teachers mostly have merit or realistic views. Both pre-service and in-service science teachers did not regard science as a social enterprise. Most of the pre- and in-service science teachers (%66 of pre-service science teachers and %73 of in-service science teachers) recognized inferential and explanatory nature of science which was consistent with the view that perceiving science as systematic investigative process. Similarly, %68 of pre-service science teachers and %74 in-service science teachers viewed scientific research as a tool to collect data as much as possible. Researcher concluded that teachers should be provided opportunities to develop more solid nature of science understanding.

In USA, Abd-El-Khalick and Akerson (2004) investigated NOS views of 28 pre-service teachers (25 female, 3 male) by means of qualitative methods. Data were collected by means of combination of open ended questionnaire (VNOS-C), in conjunction with interviews. Researchers carried out their investigation as a part of larger study in the context of science method course. Participants' views were categorized either naïve or informed. Findings concluded that the vast majority of pre-service science teachers held naïve ideas on NOS. For example, 86% of participants articulated science as set of orderly logical procedure and used single scientific method and 96% them demonstrated understanding of laws as proven, final product of science, and not liable to change. Additionally, pre-service science teachers were found to have naïve beliefs regarding to inferential, creative and theory-laden nature of scientific knowledge. The authors suggested adoption of effective strategies in an explicit reflective manner to improve NOS views.

Liu and Lederman (2007) conducted similar study with pre-service science teachers. They explored 54 Taiwanese pre-service science teachers NOS views in relation to culturally based worldviews in Far East context. Participants' conceptions of nature of science were assessed through administration of open ended questionnaire (VNOS-C) in conjunction with interviews. Their worldviews were investigated through five open questions. Participants' NOS views were categorized as either naïve or informed based on the contemporary views of nature of science. Vast majority of participants revealed naïve ideas on most aspects of NOS. For example, only %12 of them articulated role of evidence to support data instead of proof. Similarly, majority of the participants (%59) believed that theories might change because they are not proved. All of the participants held the misconception related to theories and laws such that laws were proved and more reliable. Around half of the participants (%46) viewed scientific knowledge as universal and they failed the recognize influence of norms and values of culture on scientific investigations. Distinctively, all participants were reported to recognize role of creativity in development of scientific knowledge, but they appreciated role of creativity only for certain stages of scientific investigation. About %40 of the participants recognized inferential nature of scientific knowledge and were able to differentiate observation and inference. The authors concluded that people with different worldviews may have concurrently different views about nature of science. They suggested that incorporating sociocultural perspectives and nature of science should be incorporated in the science curriculum together.

In a recent study, pre-service and in-service science teachers NOS views were investigated with larger sample (N=110 pre-service science teachers, N= 348 in-service science teachers). Data were collected by means of quantitative data collection tools (Shim, Young, & Paolucci, 2010) as a part of larger research comparing pre and post NOS views over a science method course. Participants were attending state university teacher preparation program and completed science methods course. Data were collected by means of Student Understanding of Science and Scientific Inquiry (SUSSI) scale structured on a five point likert scale. The scale included questions on: observations and inferences; social cultural influences on science; imagination and creativity in scientific investigation and; methodology of scientific investigation. Analysis revealed that there is no significant difference between pre-service and in-service science teachers NOS views. It was reported that both pre- and in-service science teachers mostly believed that scientific research does not influenced by society and culture. Additionally, majority of them recognized role of scientists' imagination and creativity only for analysing and interpreting data. Additionally, majority of them also stated that scientists used step-by-step procedure while conducting scientific investigation. Authors suggested science teacher education programs and professional development programs need to involve explicit reflective NOS emphasis.

A similar result was founded by Bell, Matkins, and Gansneder's (2011) study in which they reported naïve views of pre-service science teachers. Researchers investigated 75 pre-service primary teachers NOS conceptions as a part of investigation exploring influence of context on NOS views. Data were gathered by means of open ended questionnaire (VNOSB) in conjunction with interviews. Research results reported nearly all pre-service primary teachers' common misconceptions about nature of science. Most of the pre-service science teachers (95%) viewed scientific knowledge as absolute truths. Almost none of the participants (90%) were able to appreciate role of imagination and creativity in development of scientific knowledge. Additionally, all of them believed that theories became law when they were proven. Majority of them (80%) also indicated scientists used data and observation to prove theories, that, they also ignored role of inferences. The authors suggested the necessity of explicit NOS instruction to provide teachers with better NOS understanding.

All of the aforementioned research that investigated pre-service science teachers and in-service science teachers NOS views concluded similar results regarding NOS views. These aforementioned research studies revealed that both pre- and in-service science teachers' misconceptions related to NOS regardless of research design (e.g. sample, instrument, and methodology) and cultural context (e.g. Asian, American, Arabic).

As there has been huge focus on NOS research all around the world, Turkish science education educators have also carried out intensive research investigating Turkish pre- and in-service science teachers' NOS views (Aslan & Tasar, 2013; Tasar, 2006,; Demirdogen, 2012; Dogan & Abd-El-Khalick, 2008; Kaya, 2012; Erdogan, Cakiroglu, & Tekkaya, 2006; Ozgelen, Tuzun, & Hanuscin, 2012; Yalvac, Tekkaya, Cakiroglu, & Kahyaoglu, 2007). Next, variety of empirical research on Turkish pre-service and in-service science teachers NOS views were presented in a historical order.

In an earlier attempt to explore Turkish pre-service science teachers NOS views, Tasar (2006) conducted a study with 36 pre-service science teachers in a "History and nature of science" course. He explored pre-service science teachers' NOS views by using qualitative and quantitative methods. He administrated 48-item Nature of Scientific Knowledge Scale (NSKS) as quantitative means of data collection. Additionally, participants were asked to answer open-ended questions related to nature of science revealed in provided readings to participants within the course. Findings revealed from analysis of the NSKS instrument indicated that participants held views favouring tentativeness of scientific knowledge and mostly recognized the developmental nature of science. However, analysis of qualitative data revealed that participants possessed the pseudo relationship between theories and laws. They also viewed laws as unchangeable because laws are proved. Additionally, they also favoured universal consensus over a scientific issue. Author suggested that there has been a need to investigate why pre-service science teachers held misconceptions related to nature of science.

In the same year, similar study investigated pre-service science teachers' NOS views with larger sample this time (Erdogan, Cakiroglu, & Tekkaya, 2006). The researchers conducted the study with 166 senior pre-service science teachers. Data were collected by administration of modified version of Views on Science-Technology-Society (VOST) instrument which included of 26 multiple choice items and seven subscales. Results of the study showed that while pre-service science teachers held realistic views about nature of science some of them showed traditional NOS views. Majority of the participants (75%) believed that laws were in nature and discovered. Similarly, 86% recognized definite pattern of doing science. They stated that scientific method should follow the scientific steps to get accurate results. Almost all of the participants (94%) believed the so-called hierarchal relationship between laws and theories. Distinctively, around half of the participants recognized the subjective nature of scientific knowledge and they stated that scientists' beliefs, background might influence the data they interpret. The researchers highlighted the importance of educating pre-service science teachers scientifically literate. Therefore, they suggested further investigation to improve pre-service science teachers NOS views better.

Two years later, Dogan and Abd-El-Khalick (2008) investigated Turkish in-service science teachers' NOS views. The sample was 378 Turkish in-service science teachers. Data were collected through administration of Views on Science-Technology-Society (VOST) instrument which included of 26 multiple choice items and seven subscales. The subscales were: science and technology; influence of society on science/technology; influence of science/technology on society; characteristics of scientists; social construction of scientific knowledge; social construction of technology; and nature of scientific knowledge. Participants' NOS views were categorized as naïve have merit or informed. Findings of the study indicated that majority of the science teachers had naïve views. Majority of the teachers (more than 66%) believed that models were the copies of reality. Almost half of the teachers stated that scientific models were discovered because scientific facts were out-there to be found. Nearly half of the teachers (45%) revealed the view that there was a scientific method which was procedural, universal and step-by-step. Distinctively, majority of the teachers revealed informed NOS understanding for tentative NOS. Based on the findings of the study, researchers suggested long-term professional development programs addressing NOS effectively for in-service science teachers.

Dogan, Cakiroglu, Cavus, Bilican and Arslan (2011) reported similar results regarding in-service science teachers' NOS views. They investigated NOS views of 44 in-service (24 Female, 20 Male) science teachers as a part of larger study exploring the effect of professional development program on the development of NOS views. Data were collected by administration of administration of Views on Science-Technology-Society (VOST) instrument which included of 26 multiple choice items and seven subscales. Findings of the study showed that, in-service science teachers' naïve views on most of the NOS aspects. For instance, majorıty of them (84%) believed that the so-called hierarchical relationship between hypothesis, theories and laws. Additionally, they (35%) also held the view of single scientific method. Such that scientists needed certain procedure to construct scientific knowledge. Additionally most of them (70%) also believed that the scientific knowledge was out there to be discovered instead of constructed. However, for the empirical nature of scientific knowledge, around half of the in-service science teachers showed merit views of it. The authors recommended need for NOS education both through teacher education programs and professional development programs.

Similar findings in Turkish context were reported in another study undertaken with larger sample recently. Kaya (2012) explored 101 pre-service elementary science teachers NOS views. Data were collected by means of administration of open-ended questionnaire VNOS-

C followed by semi-structured interviews. Pre-service teachers were categorized as naïve, have merit and informed. Results revealed that most of the pre-service science teachers held informed views on tentative and creative NOS (75%). Half of the pre-service science teachers were aware of subjective NOS and also could be able to differentiate observations from inferences. However, pre-service teachers did not recognize empirical and socio cultural NOS. Additionally, they all held the misconception of hierarchical relationship between theories and laws. The author recommended that challenging and designing NOS lesson could contribute to deeper understanding of NOS.

The literature reviewed above provided empirical evidence for both Turkish and foreigner pre- and in-service science teachers' inadequate understanding of NOS. These findings suggested urgent remedy to improve NOS views of pre-service science teachers. The following section present current state of efforts undertaken to enhance NOS views.

2.3. Research on improving nature of science views

Two distinct approaches have been proposed in literature that has attempted to improve NOS views. These approaches are the implicit and explicit approach (Abd-El-Khalick, & Lederman, 2000; Abd-El-Khalick, & Akerson, 2004; Schwartz, Lederman, & Crawford, 2004). The effectiveness of implicit and explicit approaches was examined in current dissertation through the review of several studies which attempted to improve pre-service science teachers NOS views. The focus of this section was the research studies which were undertaken with pre-service and in-service science teachers since the concern of the current dissertation is to improve the pre-service science teachers' NOS views who are the future science teachers. The studies reviewed were presented under the headings of research on implicit nature of science approach and research on explicit nature of science approach. The review started with research on implicit nature of science approach first. Then, it was followed by the review of studies adopted explicit approach to improve pre-service science teachers' NOS views.

2.3.1. Research on implicit nature of science approach

The assumption endorses implicit approach was that, teachers' NOS understanding can be facilitated through process skill instruction, science content work, and doing science (Lederman, 2007).Many researchers utilized this approach to enhance pre-service science teachers' NOS understanding. However, generally, findings of the studies which adopted implicit approach to improve NOS views reported limited success of implicit approach regarding improving NOS views (Abd-El-Khalick & Lederman, 2000; Akgul, 2006; Bell, Matkins, & Gansneder, 2011; Schwarzt, Westerlund, Garcia, & Taylor, 2010). For instance, in a study conducted by Abd-El-Khalick and Lederman (2000) in USA, the researcher investigated the effect of History of Science course on college and pre-service science teachers' NOS understanding. The sample of the study was 166 undergraduate college students and 15 pre-service science teachers. The research was undertaken in the context of "History of Science" course in which participants were introduced concepts such as controversial scientific discoveries, scientific ideas within their cultural contexts, and rational, and social characteristics of scientific method. NOS instruction did not occur through the course in an explicit way. That is, the researcher expect participants to improve their NOS views without any explicit emphasis to NOS but only as a result of engage in topics from HOS. The change in participants NOS views were tracked by pre-post administration of VNOS in with follow up interviews. Analysis of pre-VNOS indicated that almost all participants held inadequate views of several NOS aspects at the outset of the study. Researcher reported that majority of participants viewed science as absolute, value free discipline seeking for truth. After completing "history of science" course, very few and limited changes in participants' views were reported. However, the researcher did not specify which NOS aspects were found to be changed. Researcher concluded that HOS course without any explicit NOS emphasis did not contribute to any change in participants' NOS views.

In another study, Turkish pre-service science teachers' development of NOS views as a result of implicit NOS instruction was tracked in an inquiry based course) (Akgul, 2006. The research was undertaken in science methods course with 35 pre-service science teachers. Within the course the pre-service science teachers were exemplified inquiry based learning incidents. The course aimed to improve pre-service science teachers' skills related to inquiry based learning and its environment. The researcher assumed that engaging in inquiry based activities through the course would improve pre-service science teachers' NOS conceptions. Data were collected by means of qualitative data collection methods such as philosophy statements, nature of science card game and reflection papers. For instance, in pre-post philosophy statements, pre-service science teachers were asked to respond the following questions; what is science? Who does science and what does it mean to do science? Findings of the study concluded that inquiry-based science course did not make any significant contribution to the development of pre-service science teachers' NOS views. The researcher reported that pre-service science teachers viewed science as body of facts, and certainty of scientific knowledge could not be discussed. The researcher extended her argument as pre-service science teachers' conceptualization of science in this way caused resistance to view science in a more contemporary view. Therefore, it was implied that the science methods course that pre-service science teachers were engaged should be well informed and equipped about NOS.

In more recent study, Schwarzt, Westerlund, Garcia and Taylor (2010) explored NOS views of American secondary science teachers through the full immersion of authentic scientific research program. The study was conducted with 40 secondary science teachers for 8 weeks. The researchers compared teachers' NOS views in full immersion scientific research program with and without explicit NOS instruction. The teachers were paired in two groups such as 19 of them in scientific research program with implicit NOS instruction and 21 of the teachers attended scientific research program with explicit NOS instruction. Both groups of teachers were paired with research scientists to engage in scientific research with scientists. However, the group with explicit NOS emphasis had weekly 2-hour group meetings in which they participated in activities addressing NOS explicitly. In those meetings, teachers had the chance discuss on the activities in scientific research program as well as they were introduced to NOS activities similar to those detailed by Lederman and Abd-El-Khalick (1998). Additionally, the teachers in the group with explicit NOS emphasis were also provided with additional activities such as black-box Earth model activity (Schwartz, Lederman, & Smith, 1999), southwest cactus inquiry and NOS concept mapping. Moreover, teachers in this group participated in reflective activities such as journal writing, and discussion. However, the teachers in non-NOS emphasis group only engage in scientific research with scientists they paired with. Data included pre-post administration of VNOS-C, interviews, and video-taped lessons. Data analysis revealed that teachers in both groups showed naïve understanding of NOS prior to the scientific research program. At the end of the intervention, teachers in the group with explicit NOS emphasis were reported to make substantial improvements in their NOS views. The teachers specifically showed substantial improvements in their understanding of empirical NOS (100%), recognition of multiple scientific methods (67%), tentative NOS (65%), role of creativity in science (58%) and socio cultural NOS (48%). The least improvements in NOS understanding for these teachers were reported for the inferential NOS (25%), definition and functions of scientific theory and scientific law (29%), empirical and socio- cultural NOS which were 16% and 10% respectively. However, the teachers in non-NOS emphasize scientific research group showed minimal improvements in their NOS understanding. Only 16% of the teachers in this group showed informed understanding of NOS in four or more NOS aspects. Based on the results of the study, the authors highlighted the importance of explicit reflective NOS instruction toward increasing scientific literacy. The authors suggested that effective programs with NOS related goals needed to have opportunities where in NOS issues were discussed and reflected upon in science contexts.

Lately, some researchers compared the influence of implicit versus explicit NOS instruction as a part of broader research exploring effect of explicit and contextual NOS instruction on American pre-service science teachers' NOS views (Bell, Matkins, & Gansneder, 2011). Participants were the 75 pre-service teachers enrolled in science methods course. Through the course participants were assigned four different classes that instructed with variations of explicit NOS instruction and the one instructed with implicit NOS instruction. Researchers stated these treatments were randomly applied. Pre-post treatment administration of VNOS-B, semi-structured interviews and classroom artifacts were used as data source. Data were analysed by means of qualitative methods, and non-parametric test were applied two make comparisons between groups. Results indicated that nearly all of the pre-instruction responses included common misconceptions related the NOS. The post instruction responses revealed that the group which received implicit NOS instruction did not show any improvement in their NOS views whereas other groups receiving explicit NOS instruction showed significant gains in their NOS views. Generally, data analysis showed a significant shift from absolute view of science towards greater understanding of human factors contributing to the tentative nature of scientific knowledge. Concerning findings of the study, the authors concluded the necessity of the explicit reflective nature of science instruction.

In sum, the literature reviewed above indicated that implicit approach was insufficient to lead change in NOS views. However, empirical evidence from literature was mostly in favour of effect of an explicit approach to gain desirable changes in NOS views of pre-service teachers. Following section provided empirical studies related to the effectiveness of explicit-reflective NOS approach.

2.3.2. Explicit- reflective nature of science approach

The second approach undertaken to improve NOS views were explicit approach which adopted the assumption that improving views of NOS should be planned for through objectives, instructional attention, and assessments. This approach intentionally draws learners' attention to aspects of NOS through discussions, guided reflection and specific questioning in the context of activities, investigations, and historical examples. Explicit approach considered NOS understanding as a cognitive instructional outcome rather than affective one. Explicit approach also has a reflective component which enables participants to reflect on their NOS learning through structured opportunities. That is, explicit approach is known as explicit-reflective approach. Research has shown that explicit reflective NOS instruction to be more effective (Abd-El-Khalick & Lederman, 2000). Explicit reflective NOS instruction may include both decontextualized and contextualized activities. Following part reviewed the studies which adopted decontextualized NOS approach. Then, empirical studies undertaken through the contextualized explicit-reflective NOS were reviewed.

2.3.2.1. Decontextualized explicit reflective nature of science instruction

Decontextualized activities introduce NOS concepts explicitly without being integrated into the specific context of science content within explicit reflective NOS instruction. Decontextualized activities might include content generic activities such as black box activities, discrepant events, puzzle solving or pictorial gestalt switches (Lederman & Abd-El-Khalick, 1998; Clough, 2006). For instance, Akerson, Abd-El-Khalick, and Lederman (2000) investigated influence of an explicit- reflective NOS instruction in the context of science method course. Participants of the study were 50 pre-service science teachers enrolling the science method course. Participants were provided explicit reflective generic activities in addition to readings and assignments (Lederman & Abd-El-Khalick, 1998).Overall, through the activities participants were provided with reflection opportunities on NOS aspects. Data were collected by means of reflection papers, VNOS questionnaire administration in conjunction with interviews. The results of the study indicated that majority of pre-service teachers held inadequate NOS views at the outset of the intervention. At the end of the intervention most of the students showed adequate NOS understanding particularly for tentative, creative NOS, and function of observation and inference, and function of theories and laws. The authors concluded that explicit-reflective NOS instruction was influential to improve NOS views. Pre-service science teachers were reported to improve their NOS views substantially but less substantial gains were reported related to subjective and socio cultural NOS. The difference in the improvement of NOS aspects were attributed the fact that intervention did not provide equal opportunities that were accessible to all NOS aspects. Same authors reported similar results from a study conducted four years later as a part of NOS study within the “conceptual change” framework (Akerson & Abd-El-Khalick, 2004). Similarly, they investigated 28 (25 female, 3 male) pre-service science teachers’ development of NOS views as a result of explicit reflective NOS instruction through content generic activities within the elementary science method course. Different from previous study, researchers used conceptual change strategies to promote NOS understanding. Changes in pre-service science teachers’ NOS views were tracked by administration of pre and post VNOS in addition to weekly refection paper and interviews. Participants’ initial responses to VNOS were used to confront and stress participants NOS misconceptions in discussion parts of the course. These kind of strategies provided participants with extensive reflection opportunities. That is, they discussed and reflected on their VNOS responses, and assigned reflection papers in response to course activities. Data analysis revealed that majority of pre-service science teachers held naïve ideas on NOS initially. However, substantial changes in NOS views for all aspects were evident at the end of the study favouring the value of explicit reflective approach. Only %14 of the participants did not show any change in their NOS views.

Distinctively, Akerson, Morrison and McDuffie (2006) explored pre-service elementary teachers’ retention of NOS views after engaged in decontextualized explicit-reflective NOS instruction. The intervention took place in the context of science methods course which aimed to help pre-service teachers to develop favourable attitudes toward science and science teaching, understanding of some science content and understanding of NOS. The sample of the study was 19 pre-service elementary teachers. Regarding explicit reflective NOS instruction, pre-service teachers participated in intensive decontextualized NOS activities (Lederman, & Abd-El-Khalick, 1998) designed to address NOS aspects. Data were collected through VNOS-B administration in conjunction with interviews. VNOS-B was administrated prior to intervention, after intervention and 5 months after the intervention to investigate retention of NOS concepts of pre-service elementary teachers. The findings of the study reported that pre-service science teachers made substantial improvements related to their NOS views at the end of the study. Majority of the participants possessed informed views for creative, tentative subjective, empirical and socio cultural NOS and the function of theories and laws after explicit reflective NOS instruction. However, results gained after third administration of VNOS- B indicated that, pre-service elementary teachers did not always retain their NOS conceptions and they sometimes returned to their original NOS understandings which were naïve views. They reported that two of the participants returned to their original NOS views for all NOS aspects.

Another study combined explicit reflective approach with metacognitive strategies (Abd-El-Khalick & Akerson, 2009). In this study, participants were assigned two different groups in an elementary science methods course. Control group received explicit reflective NOS instruction through generic inquiry activities. Experimental group received same explicit reflective NOS instruction in addition to training on metacognitive strategies which allow participants to reflect on their preconceptions deeply. VNOS-C in conjunction with interviews was used to track changes on participants’ NOS views. Participants were categorized as naïve, partially informed and informed. Naïve views referred to the views that misaligned with contemporary conception of NOS. Partially informed view presented the view that appropriate view aligned with current conception of NOS but still harbour some naïve notions. Informed view referred to the view that completely aligned with contemporary conception of NOS. Prior to intervention, participants in both groups revealed naïve views of NOS. At the end of the intervention participants at both groups improved their NOS views. However, experimental group revealed more informed views of NOS. Author concluded that influence of explicit reflective approach might be enhanced by metacognitive strategies.

In a more recent study, Cakmakci, (2012) explored 48 Turkish pre-service science teachers' development of NOS. The research was conducted in science methods course. Pre-service science teachers received explicit-reflective NOS instruction coupled with educational research. Explicit-reflective NOS instruction was undertaken through content generic activities followed by class discussions. Educational research activities involved academic article evaluations, as well as designing and conducting education research projects. During the all tasks the lecturer explicitly addressed the targeted NOS aspects and also encouraged learners to be reflective regarding their NOS views. Data were collected by pre-post administration of VNOS-C in conjunction with interviews. The findings of the study suggested that pre-service science teachers developed informed ideas about NOS over the science method course. Author also suggested that explicit reflective NOS instruction combined with educational research might be promising for better developing NOS views.

Yalcinoglu and Anagun (2012) conducted similar study with 29 pre-service science teachers in the context of science methods course. Researchers provided pre-service science teachers with content generic activities for five weeks developed by Lederman and Abd-El-Khalick (1998). Each class activity was followed by class discussion to ensure explicit-reflective NOS instruction. VNOS-C was used to explore the changes in pre-service science teachers' NOS views. Interpretative qualitative approach was adopted for data analysis. Prior to explicit-reflective NOS instruction, majority of the participants had naïve views on targeted NOS aspects. However, analysis of the post VNOS-C responses supported the empirical data favouring explicit-reflective approach for enhancing NOS views. Participants were reported to have substantial gains in targeted NOS aspects specifically for subjective and socio cultural NOS. Nevertheless, function of the theories and laws were the NOS aspects that participants showed improvement less.

Overall, the aforementioned studies indicated that explicit reflective approach through decontextualized activities is effective for improving pre-service science teachers' NOS views. Although decontextualized explicit reflective NOS instruction provided learners with opportunities to revise their NOS views without struggling science content, they were not alone sufficient to help develop deeper NOS understanding (Clough, 2006; Abd-El-Khalick, 2005; Khisfe, & Abd-El-Khalick, 2002). Highly contextualized activities within explicit reflective NOS instruction is claimed to be required for developing deeper understanding of NOS which were transferable to new situations. Additionally, contextualized activities were likely to develop teachers PCK for NOS (Abd-El-Khalick, 2001; Abd-El-Khalick, 2005; Clough, 2006; Khisfe & Abd-El-Khalick, 2002).Therefore; there is a shift in the context of NOS studies from decontextualized to contextualized ones. Subsequent section provided empirical research which used contextualized explicit-reflective NOS instruction.

2.3.2.2. Contextualized explicit reflective nature of science instruction

Contextualized NOS activities introduce NOS concepts in an explicit and reflective way embedded within science content. Contextualized explicit reflective NOS instruction involved intertwine of NOS and science content. Research suggested inquiry, history of science, and socio scientific issues and science content as contexts which provided contextualized explicit reflective NOS instruction (Abd-El-Khalick, 2001; Bell, Mulvey, & Maeng, 2012; Bell, Matkins & Gansneder, 2011; Deniz, 2007; Ozgelen, Tuzun, &Hanuscin, 2012; Rude, & Howe, 2009; Howe, 2004; Scharmann et al. 2005).

Regarding inquiry context, explicit reflective NOS instruction integrating within the inquiry context provided some cases of success. In a study which embedded explicit reflective NOS instruction into a science content course, Abd-El-Khalick (2001) explored 30 pre-service elementary teachers NOS views. The intervention both involved decontextualized and contextualized explicit reflective NOS activities. First, participants were exposed to content generic activities during the first five instructional hours. The author stated that these decontextualized activities were introductory and they aimed to sensitize NOS to the participants. Then, participants were engaged in contextualized NOS activities to integrate NOS aspects. Such that, pre-service science teachers participated in content embedded inquiry activity such as the “Rutherford’s Enlarged” activity in which students engaged in during the atomic nature of matter topic. In this activity, the instructor shot ping-pong balls into a cardboard which students could not see the inside of the box. The activity was followed by reflective prompts to facilitate students’ explicit reflections on NOS aspects. For instance, pre-service teachers did some observation, data recording and interpretation through the activity. Then, they were asked clarify the NOS ideas presented through the instructional prompts. Results were found to be evidence for substantial changes in participants' NOS views. An eight item, open-ended questionnaire (Abd-El-Khalick, 1998) were used to track changes in pre-service teachers' NOS views. The questionnaire was implemented as pre-and post-test. Data analysis revealed that participants' naïve ideas on NOS were shifted towards more favourable changes regarding NOS. For example, 43% of the participants started to perceive science as a human endeavour which involved imagination and creativity as well as collecting data. Regarding tentative NOS, 67% of the participants stated that both laws and theories would change. To be brief, the author stated that 53% of the participants conveyed more informed views of NOS at the outset of the intervention. Author attributed the favourable change to content embedded activity within the reflective approach.

Another study was undertaken by Deniz (2007) in the context of an introductory science course with 166 pre-service science teachers. The researcher investigated pre-service science teachers' development of NOS views as a part of research exploring factors related to NOS understanding in an introductory science course. The main focus of the course was science process skills, hypothesis testing and nature of matter. The course involved weekly laboratory meetings in which participants involved in inquiry based activities as well as theoretical part. In the laboratory sessions, participants first engaged in content generic activities such as trick tracks, young women-old women, aging president, the tube, and the cubes (Lederman, & Abd-El-Khalick, 1998). After involving in content-generic activities, participants were engaged in inquiry oriented sessions. For instance, pre-service science teachers participated in Rutherford's Enlarged (Abd-El-Khalick, 2001) activity in which they re-do an experiment related to atomic theory. After each activity, pre-service science teachers were asked to write reflection paper on NOS aspects. Data were collected through pre and post administration of VNOS-B with follow-up interviews. Analysis of data sources indicated that the explicit reflective NOS instruction in an inquiry oriented laboratory was effective in leading positive changes in pre-service science teachers' NOS views.

Similar but more recent study was undertaken in inquiry based laboratory course (Ozgelen, Tuzun, & Hanuscin, 2012). The research aimed to explore development of pre-service science teachers NOS views in the context of explicit-reflective and inquiry based laboratory NOS instruction. A total of 52 pre-service science teachers were the sample of the study enrolled inquiry based laboratory course. Pre-service science teachers were engaged in inquiry based experiences coupled with explicit reflective NOS instruction. Change in pre-service science teachers NOS views were tracked by means of pre-post administration of

VNOS-C. Similar with the previous research, findings of the study revealed that pre-service teachers developed informed NOS understanding for most of the NOS aspects.

Additionally, science process skills (SPS) as a context were suggested to be effective to improve NOS views (Bell, Mulvey, & Maeng, 2012). In this approach, authors suggested starting lessons with an activity based approach designed to teach science process skills such as observing, inferring, experimenting etc. Then, learners were encouraged to reflect and discuss nature of science in the context of activity and related science process skills. Authors investigated effect of SPS as a context to developed better NOS views of pre-service science teachers. Total of 17 pre-service science teachers were administered VNOS-C questionnaire before and after attending science methods course which adopted process skills based approach. Pre-service teachers were reported to shift their naïve NOS ideas toward informed NOS views at the end of the study.

Socio scientific issues also used to contextualize explicit reflective NOS instruction. For instance, Bell, and Matkins (2007) used explicit reflective NOS instruction in the context of global climate change in science methods course. A subset of 15 pre-service elementary teachers enrolled the course. To explore participants' development of NOS views, open ended questionnaire (VNOS) were administrated before and after intervention. Findings of the study reported improved NOS views as well as application of NOS conceptions into socio scientific issues. Three years later, in a follow up investigation, same researchers compared development of pre-service elementary teachers NOS views within global climate change context versus as a stand- alone topic (Bell, Matkins & Gansneder ,2011). Pre-service teachers in global climate change, received NOS instruction embedded in global climate change context, whereas the ones in stand-alone topic only received explicit reflective NOS instruction. The development of pre-service teachers NOS views was found to be significant regardless of context. However, pre-service elementary teachers in global climate change context were reported to be able to reflect their NOS understanding in other socio scientific issues.

Another kind of context used for contextualized NOS instruction is history of science (HOS). Multiple approaches were advocated for HOS contextualizing for explicit reflective NOS instruction such as, utilizing historical case studies, integration of historical short studies into content and utilization of scripts reflecting scientists' life (Clough, 2006, 2007). For example, Howe and Rudge (2005) suggested HOS based unit to improve NOS views. In their research, 81 pre-service elementary teachers' NOS views were tracked in the context of HOS. The authors investigated the impact of eight series of lessons based on history of research on sickle-cell anaemia coupled with explicit-reflective NOS instruction. Pre-post administration of VNOS-C in conjunction with interviews was used to decide the impact of the HOS based unit on NOS views. The findings suggested improvements and enrichments in pre-service sciences teachers' NOS views such as tentative, subjective NOS, and validity of observational methods. Authors attributed to positive change in NOS views to contextualized example provided with HOS.

In more recent study, researchers investigated the changes in NOS views during a historically based unit (Rudge, Cassidy, Fulford, & Howe, 2013). Participants of the study were 130 pre-service elementary teachers enrolling a course of three series of lessons based upon HOS. The course included unit on phenomena of history of industrial melanism within the introductory biology course. The research was undertaken through three instructional sessions. All sessions were based upon the history of research on industrial melanism and involved guided discussions, individual and group work as well as explicit reflective NOS instruction. Explicit reflective NOS instruction was ensured in the context of history of industrial melanism. Data were collected by means of pre-post administration of VNOS in conjunction with interviews. Analysis of data revealed that participants developed deeper understanding of NOS for some NOS issues. Particularly, participants became more sophisticated related to NOS aspects such as the role of experiments and evidence. Researchers concluded that explicit-reflective NOS instruction was necessary but use of multiple examples form HOS might help students to gain more meaningful NOS understanding.

In some cases, explicit reflective NOS instruction has been integrated into science content. For instance, Scharmann et al. (2005) designed an instructional unit on evolution and intelligent design debate coupled with explicit reflective NOS instruction. Researchers conducted action research in a laboratory course with pre-service secondary science teachers. Researchers designed explicit NOS instructional unit within the course to help pre-service science teachers enhance their NOS concepts. The unit was around 10 hour session of 5-E inquiry based instructional sequences. The unit included first discussion on pseudo-science. The aim of that was to give the idea that science involved some level of uncertainty. Then, the participants were provided three theories such that evolution, intelligent design and umbrellaology. Participants were required to place these theories on a scientific to non-scientific continuum. The researchers aimed to address the idea that science developed some criteria to make scientific decisions. Finally, participants were involved in inquiry activities which were designed to reflect that scientific theories models were human construct and they assisted in solving problems. Data were collected by means of written artifacts of participants and videotaped whole class discussions. Findings of the study indicated that participants were able to demarcate science from non-science at the end of the unit implementation. The researchers concluded the enhanced views of the pre-service science teachers were due to the explicit-reflective manner of NOS instruction. Additionally, the sequence of the unit that was designed to introduce NOS was also influential to improve NOS views.

In a recent study, NOS was addressed explicitly and reflectively during teaching astronomy and space (Buaraphan, 2011). Through the intervention, participants' development of NOS views and translation of these views into practice were explored through astronomy and space content. Regarding investigating development in NOS views, the study conducted through intensive one week NOS workshop in Thailand. Particularly three volunteer in-service teachers were the focus of the study. The workshop included content generic NOS activities as well as contextualized explicit NOS instruction. Contextualized explicit reflective NOS instruction included modelled NOS lessons which integrated NOS into teaching of astronomy and space. Additionally, participant teachers were provided reflection opportunities on their NOS learning. The Myths of Science Questionnaire (MOSQ) was employed before and after the workshop to explore changes in teachers' NOS views. The questionnaire was the 3-likert scale and participants' responses were categorized as informed, uncertain and disagree. At the end of the intervention participants revealed informed conceptions for the differentiation of science and technology, and function of theories. Researcher explained the limited change due to the resistance of the ideas to change and the limited time of the workshop.

In another study Wahbeh (2009) designed explicit-reflective NOS instruction enriched with content based examples to improve 19 Palestinian in-service science teachers' NOS views (Wahbeh, 2009). For this purpose, four inquiry based activities chosen from Palestinian national science curriculum were used. These activities were used as a content based part of the larger intervention which embodied content-generic activities as well. These activities were selected from the topics of “atomic structure and elements”, “atmospheric pressure”, and “electricity and light”. During the intervention, while doing inquiry based activities related the aforementioned science topics, participants were provided opportunities to think NOS in those science contexts. To track changes in in-service science teachers' NOS understanding VNOS-C and semi-structured interviews were used. Findings indicated that majority of the participants held inadequate views of NOS prior to the intervention. However, at the end of the intervention, the researcher reported favourable changes in in-service science teachers' NOS views. For instance, %68 of the participants used the word "empirical" to differentiate science from other disciplines. Similarly, %68 of the participants recognized that scientists made sense of natural phenomena from different paradigms and different point of views. About half of the participants (%57) stated that scientific knowledge could be reasoned through argumentation and inference. Regarding tentative NOS, %74 of the participants showed informed views. Concerning socio cultural NOS, %63 of the participants agreed that science reflected norms and values of the society in which it was practiced. Despite of the these significant shifts in various aspects of NOS, few of the participants (%32) showed development in their views related to theories and laws. Overall, the researcher reported considerable changes in in-service science teachers' NOS views due to the nature of the explicit-reflective NOS intervention which embodied "content -rich" elements.

Distinct from the previous contextualized explicit reflective NOS studies, Seung, Bryan, and Butler (2009) combined different contexts coupled with explicit reflective NOS instruction. The study was undertaken with 19 pre-service science teachers in the science methods course over two semesters. Participants were engaged in instructional NOS activities designed based on three instructional approaches. The approaches were explicit, not context-based; explicit, context-based; and explicit, case-based. The explicit, not context-based involved a NOS activity unrelated to the content currently being taught. The cube activity was chosen for this approach (Abd-El-Khalick &Lederman, 1998). The explicit, context-based involved an NOS activity that was more related to the content such that pendulum activity was chosen within that content. The explicit, case-based approach utilized the use of historical narratives. Within this approach pre-service science teachers participated in two activities in which they read a historical case and in the second activity they developed a historical case. Adapted version of VNOS, semi structured interviews and students' written artefacts were used as data source. After intervention, pre-service science teachers showed substantial changes in their NOS understanding. Additionally, it was reported that pre-service science teachers perceived each NOS activity in different context helpful for their future teaching. Author concluded that each context had their strengths and each context was complement to each other. Thus, using various instructional contexts could contribute to develop deeper NOS understanding.

In summary, research indicated that contextualized explicit- reflective NOS approach were more influential in providing opportunities for pre- and in-service teachers to deeply understand NOS concepts and to transfer their NOS understandings into different contexts including teaching. In addition to achieving deeper NOS conceptualizing which was necessary condition for effective NOS instruction, such contexts also enabled teachers to learn variety of examples, activities, demonstrations related to NOS. That kind of knowledge of NOS also promoted transfer of NOS understanding into teaching practices. Accordingly, following section provided insights on how pre-service science teachers with adequate NOS understanding transfer their NOS knowledge into instructional practices and other factors impact facilitate or impede this translation.

2.4. Translation of Nature of science conceptions into practice

Research claimed that there has been no clear cut relationship between NOS views and effective NOS instruction (Abd-El-Khalick & Lederman, 2000). Although having adequate NOS understanding have been necessary for effective NOS instruction, it does not guarantee for accurate and effective NOS instruction (Abd-El-Khalick & Lederman, 2000; Lederman, 2007; Brickhouse, 1990). Lederman (1992) concluded more complex relationship between NOS understanding and NOS teaching practices, that is, many other factors such as self-efficacy for teaching NOS, intentions for teaching NOS and some level of PCK for NOS (Abd-El-Khalick, & Akerson, 2004; Bilican, Cakiroglu, 2012) also played an important role in translation of NOS concepts into practice. As a result research efforts shifted towards investigating teachers' NOS practice and the factors influence their effective NOS instruction.

An earlier attempt focused on pre-service science teachers' translation of NOS views into practice, and the factors mediated this translation (Abd-El-Khalick, 1998). Study was conducted with fourteen pre-service science teachers enrolled in science methods course. Within the course, pre-service science teachers were exposed to contextualized and decontextualized explicit-reflective NOS instruction and also experienced NOS teaching modelling. Additionally, all pre-service teachers completed 12-week full time internship in school setting. To explore pre-service science teachers' understanding and teaching of NOS, data collected by means of VNOS administration in conjunction with interviews, field notes, classroom videotapes, lesson plans created by participants, and reflection papers. Analysis of data revealed that all participants achieved adequate understanding of NOS. However, they could not able to reflect their NOS understanding into their instructional design and practices in an explicit and reflective way. Author concluded that pre-service teachers need to some level of PCK for NOS to be able to address NOS in their instructional practices accurately. Thus, necessary scaffolds, and support for NOS teaching should be provided in teacher education programs as well.

In a follow up study, 15 pre-service science teachers instructional planning was explored (Lederman, Schwartz, Abd-El-Khalick, & Bell, 2001). Pre-service science teachers were required to design lessons within two-week internship. These participants all attended a program on teaching and learning NOS before. Through their internship, seven pre-service science teachers were fully supported such as through providing feedback, helping out for NOS objectives and NOS activities. These supported seven pre-service science teachers who held adequate understanding of NOS views were successful in addressing NOS aspects in their lesson plans. Authors attributed this success to following factors; pre-service science teachers' NOS conceptualization, their knowledge related to science content, their PCK for NOS and their intentions to teach NOS.

After a year later, Akerson and Abd-El-Khalick (2003) conducted a case study exploring a student teacher's NOS teaching practice that had appropriate conceptualizing of NOS; intentions to teach NOS, and their belief that students could learn NOS. Student-teacher's efforts to implement NOS into her teaching were tracked through her internship for a year to decide success and challenge of her while she was implementing NOS into her teaching. Data were collected by means of observed, videotaped teachings in her class. Student-teacher were provided so-called "socially mediated contextual" support. That kind of support included NOS resources, lesson feedback and debriefings, clarifications, scaffold on her lesson plans, and NOS lesson modelling. Findings of the study indicated that, although she had intention to teach NOS, her NOS teachings were lack of explicit-reflective component at the beginning of the internship. It was revealed that she improved her NOS teaching towards to more explicit-reflective NOS teaching as a result of continuous support. Authors concluded that, even teachers achieved NOS teaching rationale and belief that students could learn NOS, they still need continuous contextual support to be able to address NOS explicitly and reflectively.

Similar study conducted with a pre-service elementary teacher to explore the NOS teaching of pre-service elementary teacher and impact on this teaching on first grade students NOS conceptualization (Akerson, &Volrich, 2006). The pre-service teacher, had adequate conceptions of NOS, intention to teach NOS and also trained on how to teach NOS. Additionally, she was provided with support regarding to NOS teaching in weekly meetings. Distinctive form the previous study, pre-service teacher successfully implement explicit reflective NOS lessons, and favourable changes were detected in first grade students' NOS views. Authors concluded that, if pre-service teachers trained well (e.g. including developing NOS views, experiences on implementing successful NOS lessons, etc.,) related to teaching NOS, pre-service teachers could implement explicit reflective NOS lesson effectively.

Mellado, Bermejo, Blanco and Ruizz (2008) carried out a research to explore one prospective biology teacher's nature of science conceptions, learning of these conceptions and teaching science. The prospective teacher was a biology graduate. To understand the prospective teacher's conceptions of science and science teaching, Inventory of Teacher_ Scientific and Pedagogical Beliefs designed by Porla´n (1989) was used. Additionally, interviews, classroom observations, planning documents and videotapes were used to observe the prospecticve teacher's behavior in class. Analysis of the results indicated that, although the prospective teacher's views of natüre of science was in accordance with the contemporary philisophy of science, it was contradictory to his teaching. While he was teaching he perceived students only passive receptors of knowledge with little student active participation. Additionally, he did not transfer his beliefs regarding nature of science. The authors cocnluded that, the traditional education of the prospective teacher which only focused on knowledge of the subject was the one of the main causes of the prospective teacher's manner in class. Additionally, they cocnluded that, the prospective teacher's initial teacher education did not help them to construct required PCK for teaching NOS. They suggested that teacher education programs needed to help prospective teachers to be aware of their own conceptions attitudes and classroom practice.

Another case study investigating junior pre-service science teacher teaching nature of science in Turkey (Ozdem & Bilican, 2012) as part of larger study investigating pre-service science teacher's NOS and argumentation teaching. The study was undertaken in teaching practice course. The pre-service science teacher held adequate views of NOS and rationale to teach NOS initially. The pre-service science teacher voluntarily taught five classes in a public school. After his each teaching, he and one of his mentors who were experienced in NOS and argumentation teaching and one of the authors in this case were met. Within the meetings the pre-service science teacher got feedback about his teaching regarding NOS as well as get opportunities to reflect on his teaching. The data were collected by means of interviews, video-taped teaching lessons, audio recorded weekly meetings and reflection papers. Analysis of the qualitative data indicated that, he had difficulties in integrating NOS in his lessons for his first three teaching sessions. In the meetings, the mentor suggested him the ways he could integrate NOS. That is, the mentor guided him how to provide examples to address NOS within a content, to ask questions to illustrate NOS. Then, for the fourth and fifth lessons, the pre-service science teacher showed efforts to keep up NOS discussions, and also used HOS to focus NOS explicitly. Additionally, it was detected that he tried to focus on more NOS aspects. The authors concluded that feedback and reflection opportunities were contributed the pre-service science teacher's ability to teach NOS.

In Turkey, Demirdogen (2012) also investigated translation of pre-service science teachers' into their lesson plans. Participants were 30 pre-service science teachers from variety of universities. Participants were engaged in explicit reflective NOS activities first then they were asked to create lesson plans. After they prepared their lesson plans, they participated in a workshop in which they instructed how to integrate NOS into lesson plans. After workshop, participants were given chance to revise and resubmit their lesson plans. Interviews, and lesson plans were collected as data source. Analysis of lesson pans indicated that the degree participants integrated NOS was varied. Although participants held informed views of NOS, three of the participants did not reflect their understanding in lesson plans. Participants were found to be more successful at assessing NOS and including explicit reflective instructional strategies. Researcher reported that there was no clear cut relationship between NOS views and translation of these views into practice. However, participants used mostly the NOS aspects which they held informed views. Additionally, researcher reported that participants were able to better reflect their NOS understanding into lesson plans if they were aware of students' misconceptions on NOS and if they know required instructional strategies (e.g. explicit or implicit approach) to teach NOS.

More recent study explored six Turkish pre-service chemistry teachers' NOS instructional practices were explored (Bektas et al., 2013). Participants' NOS instructional practice were examined within the science teaching methods course in which participants were required to prepare instructional sequences and present them as microteaching sessions. Through microteaching sessions, other participants observed their peers teaching. Participants were required to prepare lesson plan twice during the course. Data were collected by means of lesson plans and written artefacts and interviews. The results indicated that participants mostly integrated tentative NOS and function of theories and laws into their lesson plans. Interviews revealed that participants failed to explain how they used instructional strategies to address these aspects explicitly. Additionally it was reported that pre-service science teachers had difficulties while assessing NOS conceptions in their plans.

To be brief, studies conducted with pre-service science teachers indicated many factors impacting on translation of NOS views into instructional practices. In earlier studies, these factors were identified as instructional constraints, student's motivation, teaching experience (Abd-El-Khalick, 1998, Lederman, 1999, Lederman et al. 2001). Additionally, intention to teach NOS and belief that students could comprehend NOS concepts were another influential factor on translation of NOS views into classroom settings. Recently, development of PCK for NOS was standing as one of the main motivation for addressing NOS in teaching in an accurate and effective way (Akerson & Abd-El-Khalick 2003; Akerson & Volrich, 2006; Hanuscin, Lee, & Akerson, 2011).

However, the studies reviewed above reported success in translation of NOS views into teaching practice if student- teachers were mostly provided one-to one, on-site support for their NOS practice. In many contexts that kind of support might not be practical considering the time and effort issues. Therefore, it is better if teacher education programs prepare pre-service teachers effectively which enable them to be skilled enough before they start to teach NOS to students in class. In that sense, lesson plan preparation integrating explicit reflective NOS instruction as in present study, could serve as a tool to develop pre-service science teachers’ ability to teach NOS in advance. As a result pre-service teachers would need less support while they were in actual teaching because lesson planning integrated explicit reflective NOS instruction would provide them authentic teaching experiences. Additionally, systematic analysis of lesson plans would sign inefficiencies of pre-service science teachers regarding NOS teaching which enable teacher educators to remedy pre-service teachers in advance for their NOS teaching.

CHAPTER 3

METHOD

The main focus of the study was to explore pre-service science teachers' understanding of NOS and translation of this understanding into their instructional planning for teaching NOS within the contextualized explicit reflective NOS based approach. The study, first investigated pre-service science teachers' development of NOS views as a result of explicit reflective NOS instruction in the context of HOS based science method course, which was designed to improve pre-service science teachers' both NOS views and NOS related instructional practices. Second, the present dissertation aimed to explore pre-service science teachers' trajectory progress of translation of NOS views into instructional planning. The following research questions were explored in the present dissertation:

I. How do pre-service science teachers' NOS understandings change in the contextualized explicit reflective approach?
II. How is the progress trajectory of pre-service science teachers in relation to integrating NOS into their lesson plans as a result of feedback in the contextualized explicit reflective approach?
III. What learning experiences do contribute to pre-service science teachers' ability to integrate NOS into their instructional plans?

The study was undertaken in the fall semester of 2009-2010. Data collection was continuous and spanned through the science method course which was lasted 13 weeks. Data were collected by means of open ended questionnaire in conjunction with interviews, student journals and lesson plans and interviews. Al the data source was examined to find out evidences regarding participants' NOS understanding and their NOS instructional planning.

The rest of the chapter introduced the research design regarding method of the study, participants, context of the study, data collection tools, data collection, data analysis and trustworthiness of the study.

3.1. Research design

Present study was an interpretive qualitative research focused on meanings that participants ascribed to the emphasized NOS aspects. A qualitative research which is not classified as phenomenological, grounded theory, narrative analysis, or critical or ethnographic study might be called as basic qualitative study (Merriam, 2009). Merriam (2009, p. 22), defines central characteristic of interpretative qualitative research as one's construction of reality as a result of interaction with social world in which researcher is interested in exploring the meaning of the construct that one is involved in. The meaning of the construct refers to "not discovered but constructed. Meaning does not inhere in the object, merely waiting for someone to come upon with…. Meanings are constructed by human beings as they engaged with the world they are interpreting" (Crotty, 1998, pp.42-43). Basic qualitative research is seeking to explore "(1) how people interpret their experiences, (2) how they construct their world, (3) what meaning they attribute to their experiences" that is "to understand how they make sense of their lives and experiences" (Merriam, 2009, p. 23). Application of description of basic interpretative research in the current study, there has been two main focuses of the study. First one was the meanings that participants ascribed to the emphasized NOS aspects. The second focus of the study was how pre-service science teachers' interpretation of targeted NOS aspects was attributed to their NOS instructional planning.

3.2. Participants

Participants were volunteered seven pre-service science teachers enrolled in science method course offered in fall semester of 2009 in the department of elementary education in the one of the biggest university in Turkey. All participants were at their third year and fifth semester of science teacher education program. Participants' age ranged between 21 to 26 years. One of the participants was male and six of them were female. All participants have similar background such that completed same amount of credit of mandatory both science and educational courses. The elementary science education program included the total of 92 mandatory credits. A total of 45 credits of these mandatory courses were consisting of science courses such as fundamentals of physics, chemistry and biology. The participants took these science courses in their first and second year of the elementary science education program. Rests of the credits were mandatory educational courses which were probability and statistics, educational psychology, measurement and assessment and instructional principles and method courses. These courses were offered to the participants starting from first year of the students until their last year in the program. In the current study none of the participants enrolled any course which has NOS emphasis. That is, it was first time that participants were taking the science method course addressing NOS within an explicit reflective approach. In other words, they were not exposed to any NOS instruction prior to the science method course.

3.3. Context of the study: Description of an elementary science method course

The study was undertaken through an elementary science methods course. The course was offered during the fall term in 2009-2010 about 13 weeks in total within the semester. It was a 4 credit hours and mandatory course in the elementary science education program. It was held weekly in 5 hours throughout the semester. The course consisted of 3 hours of theory session and 2 hours of practice session. In the theory session participants were introduced major concepts of the topic. The practice session of the course was held for 2 hours in a week. Participants were intensively engaged in discussions, hands-on activities and reading assignments in weekly held 2 hours practice sessions. The aim of the elementary science method course was to provide participants with theoretical framework for teaching science at elementary level, and with desired attitudes toward science and science teaching as well as deeper understanding of nature of science. It included hands-on activities, readings activities and assignments, to provide insights on scientific literacy, science process skills and nature of science. Another important task of the course was lesson plan preparation. Since lesson planning was one of the major activities of the course, participants were assumed to have skills required to prepare lesson plans.

3.4. Data collection

Merriam (2009, p.23) suggested to use, interviews, document analysis and observation as a data collection tool in basic qualitative studies. Taking into consideration this notion, data were collected by means of open ended questionnaire, named as Views of Nature of Science Questionnaire (VNOS) (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). In addition, student journals (reflection paper), interviews, and lesson plans were used as data sources. While open ended questionnaire, students' journals and interviews were used to provide evidence for the change if any on participants' understanding of NOS as a result of explicit reflective NOS instruction in a HOS based context science method course, lesson plans, interviews, reflection papers and videotaped classes were used to project participants' instructional planning regarding NOS teaching.

3.4.1. Views of nature of science questionnaire

In order to determine teachers' NOS views, modified version of the views of nature of science questionnaire, form C (VNOS-C) was administered in conjunction with semi structured interviews to provide validity of the instrument (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). All participants responded the questionnaire twice over the science method course as at the beginning of the science method course and at the end of the science method course. The sample of questionnaire is provided in Appendix A. The Views of Nature of Science Questionnaire–Form C contains 10 open ended questions addressing each particular NOS aspect. The questionnaire was modified by adding some additional questions from other VNOS questionnaire forms (e.g. VNOS B, VNOS D+). The need for modification of the VNOS-C was determined by me as a researcher based on my past NOS research experiences with pre-service science teachers. I believe that, modification enabled to get more detailed responses from the participants. As a modification, I split up some questions in two or add some additional follow-up questions which would provide more detailed responses. Through the current research, participants' views about (a) empirical nature of science (b) subjective nature of science, (c) tentative nature of science (d) role of creativity and imagination in development of scientific knowledge, (e) inferential nature of science, (f) socio cultural embeddness of scientific knowledge and (g) the function and definition of theories and laws were considered. Open ended questionnaire utilized in current study was used and validated previously by lots of researchers (Schwartz & Lederman, 2002; Schwarzt, Lederman, &Crawford, 2004; Akerson, Buzelli, & Donnelly, 2008).The questionnaire was also provided in Appendix. Questions and related NOS aspects were given in Table 1. However, these aspects were not limited to the only one question, because of interdependent nature of all NOS tenets; one could seek for more than NOS tenets understanding through one question.

The reason for use of open ended questionnaire was allowing respondents to express and rationalize their own ideas on targeted aspects of NOS and avoid the problems arising from use of standardized forced choice paper pencil NOS assessment instruments (Bell et al., 2002).

Table 1. VNOS-C questions and related NOS aspects

Question number	The NOS aspects question refers to
1	General ideas about science
2	Empirical NOS
3	Nature and function of experiments
4	Tentative NOS
5	Inferential NOS and subjective NOS and tentative NOS
6	Nature of models, tentative NOS, and inferential NOS
7	Nature of models and inferential NOS
8	Imaginative and creative NOS
9	Functions of theories and laws, distinction between theory and law
10	Socio cultural NOS

3.4.2. Interviews

Within the data collection process, two different kinds of interviews were conducted. One of them was related to participants' VNOS-C responses and one of them was related to participants' NOS instructional planning. The interviews related to VNOS-C responses were used to validate participants' responses to open ended questionnaire (VNOS-C) as suggested by the developers of the questionnaire (Lederman et.al., 2002; Abd-El-Khalick, 1998). It was conducted at the beginning and end of the science method course as pre-and post-interviews. Interviewing %15-20 of the participants was found to be sufficient by the questionnaire developers (Lederman, et al., 2002; Abd-El-Khalick, 1998). Considering the small sample size, I intended to interview with all of the participants to elaborate and clarify their responses to VNOS-C questionnaire. Only five of the participants were agreed to interview at the beginning of the science method course but all of the participants volunteered to interview at the end of the science method course. The interview was semi-structured consisting of the VNOS-C questions and took around 30 minutes. Through the interviews, participants were provided with their responses to the questionnaire and asked to elaborate their answers. Another interview also conducted to understand participants' NOS instructional planning better at the end of the science method course. The interview was semi-structured and conducted with all of the participants. It was included questions which were roughly related to participants 'experiences and perceptions on writing NOS objectives, integrating NOS into activities in an explicit and reflective way, NOS evaluation, and their perceived improvement regarding NOS instructional planning. Interview questions were provided in Appendix B. The interviews were spanned around 25 minutes. These interviews used to triangulate data for participants' instructional planning for NOS teaching.

3.4.3. Written journal

The aim of e written journal was to encourage participants to think about their NOS teaching. At the end of the intervention, pre-service science teachers were asked to write about their perceptions of NOS teaching. To trigger them to write following questions were provided:

a. Do you think teaching NOS is necessary?
b. Do you plan to teach NOS in your future teaching if so in which ways? (what will be your strategy, how you will teach)
c. Do you feel efficient enough to teach all NOS aspects? Explain your answer (is there any NOS aspects you think you are not able to teach, or some aspect you could teach better)

3.4.4. Lesson plans

Participants were asked to prepare NOS integrated lesson plans by means of using HOS enabling researcher to track their NOS instructional planning. Pre-service science teachers were mainly responsible to plan teaching NOS in their lesson plans through a HOS based approach in addition to planning science content to be taught. Pre-service science teachers were prepared five lesson plans, and each lesson plan were given feedback. Each lesson plan were required to be science and technology curricula related, and at the grade level of between K-6 to K-8. However, the content to be planned of the lesson plans was chosen by pre-service science teachers by considering curriculum. They were responsible to include mainly three parts in lesson plans: objectives, description of activities and evaluation parts. In the objectives part of the lesson plan participants were supposed to write lesson objectives related to both science content and NOS, in the description of activities parts of the lesson plan, they were expected to write how they would teach the lesson and every step they would do while teaching lesson. Lastly, in the evaluation part of the lesson plan participants were expected to describe how they would assess if the targeted objectives were achieved.

Table 2 lists the present study’s research questions and the instruments used for each research questions with a validation strategy.

Table 2. Outline of research questions and data collection tools with timeline

Research Questions	Data collection tools and timeline
How do pre-service science teachers' NOS understandings change in the context of explicit reflective HOS based approach?	VNOS were administered at the beginning and end of the science method course in conjunction with interviews
How is the progress trajectory of pre-service science teachers in relation to integrating NOS into their lesson plans as a result of feedback in the context of explicit reflective HOS based approach?	Lesson plans collected over the science method course for five times Interviews conducted at the end of the science method course Written Journal
What learning experiences do contribute to pre-service science teachers' ability to integrate NOS into their instructional plans?	Interviews conducted at the end of the science method course

3.5. Intervention

In present study explicit-reflective NOS instruction was undertaken both through decontextualized and contextualized activities. The aim of decontextualize activities were to familiarize participants with NOS whereas the aim of the contextualized activities were to provide them opportunities to internalize NOS concepts. First, participants were exposed to decontextualized NOS activities for the first four weeks. At the fifth week of the intervention, participants were involved in HOS-NOS familiarizing task to be familiar with contextualized explicit –reflective NOS instruction. In that week, participants were engaged in tasks such as writing a reflective journal related to HOS, critiquing curricula with respect to NOS inclusion and reading an empirical article related to explicit reflective NOS. After fifth week, the intervention shifted to the contextualized explicit reflective NOS instruction. In the rest of the intervention,HOS contextualized NOS activities were provided with participants. HOS contextualized tasks were provided in conjunction with lesson planning activity. Following section presented the detailed explanation of each tasks provided within intervention.

3.5.1. Decontextualized nature of science instruction

Participants were exposed to decontextualized explicit reflective NOS instruction through content generic activities (Lederman & Abd-El-Khalick, 1998). Decontextualized explicit reflective NOS instruction were undertaken through the science method course through five weeks in total which were 20 hours intensive theory and practice sessions of science method class. Starting from the second week of the science method course, participants were engaged in content generic NOS activities addressing seven target aspects of NOS through five weeks. Each activity had been undertaken through. During intervention, pre-service science teachers were firstly introduced the related concepts such as definition of science, and who are scientists through an interactive discussion through providing them with the stereotypical image of scientists. Additionally, the difference between science and non-science had been discussed through hands-on/minds on activity which was “knowledge claim statements (Scharman et al., 2005) in present case. That is, participants were supposed to place some claims on a continuum from less scientific to more scientific. In addition to these, the activities of “Tricky tracks”, “Young? Old?”, “The aging president”, “Real fossil real science”, “An activity for the first day of class”, “Sequencing events”, and “Black box” served to address the difference between observation and inference, the empirical basis of scientific knowledge, imaginative, subjective and tentative nature of scientific knowledge. In addition to these, the function of theories and laws were emphasized during the activities explicitly. Through the activities participants were presented each targeted NOS aspect through explicit reflective NOS instruction. That is, participants were encouraged to discuss and reflect their ideas about the related NOS issue. After each activity, main targeted NOS issues were emphasized (wrapped up) either orally or through creation of NOS charts by the instructor enabling participants to pay attention to their unclear NOS ideas. All activities were chosen purposefully to be content generic to encourage participants to focus on NOS content rather than specific science content. Discussions of NOS issues through content generic activities decreased the pressure of science content and enable them to revise and refine their ideas on NOS rather than scientific content (Abd-El-Khalick, 2002). The content generic activities were also appropriate for those with limited science background by encouraging them think about science (Akerson, Abd-El-Khalick, & Lederman, 2000). In short, these introductory activities served to provide students with a NOS framework and familiarizing them to target NOS aspects. These aspects became a theme embedded the remaining course activities. Table 3 showed representing each activity with targeted NOS aspects and the summary of content generic NOS activities conducted each week.

Table 3. Outline of decontextualized nature of science activities

Course weeks	Activities	Targeted NOS aspect
1st week	Draw a scientists	Introduction of major concepts such as science, scientists, how scientists work
	Knowledge claim statements	Limits of science and what makes our knowledge be scientific.
2nd week	Card exchange activity	Introduction of major concepts such as science, scientists, how scientists work
	Tricky Tracks	Difference between observation and inference Subjective nature of scientific knowledge
	Young? Old The Aging President	Subjective nature of scientific knowledge Difference between observation and inference Social cultural embeddness
3rd week	Real fossil real science	Role imagination and creativity in development of scientific knowledge, Empirical basis of scientific knowledge, Role of scientists' inference in development of scientific knowledge Subjective nature of scientific knowledge
	An activity for the first day of class	Influence of scientists' subjectivity on scientific knowledge, Tentative nature of scientific knowledge Role imagination and creativity in development of scientific knowledge Function and definition of theory and laws.
4th week	Sequencing Events	Empirical basis of scientific knowledge, Subjective nature of scientific knowledge, Socially culturally embeddness,
	Black Box	Function and definition of theories and laws Empirical basis of scientific knowledge Subjective nature of scientific knowledge Tentative nature of scientific knowledge Role imagination and creativity in development of scientific knowledge

3.5.2. History of science-nature of science context familiarizing tasks

Throughout the fifth week of the course, participants were provided opportunities to reflect and improve their NOS views verbally by means of and written artifact as they encounter course readings and activities in practice session of the science method course. Before participants were provided HOS context learning opportunities through practice session of science method course, they assigned to some tasks such as (a) writing reflective journal related to HOS; (b) critique of curricula in terms of NOS; and (c) reading and discussing of an article on explicit reflective NOS instruction. Writing a reflective journal regarding HOS included discussion of questions like: (a) what HOS is, (b) the use of HOS in teaching science and (c) providing an example related to HOS. The goal of these essays was to sensitize pre pre-service science teachers to HOS and give basic information about the terms related to HOS, since HOS was utilized to contextualize science method course. Secondly, pre pre-service science teachers were expected to examine Turkish science and technology curricula with respect to NOS aspects. The aim of the current task was to make students aware of curricula in terms of NOS. It also enabled them to acquire the knowledge of content and objectives as well as evaluate these regarding NOS integration perspective. They wrote a journal covering the possible answers of following questions related to investigation of curricula with respect to NOS

I. What is place of nature of science in the vision of science and technology curriculum?
II. How nature of science is reflected in the aims of science and technology curriculum?
III. Chose a subject from the curriculum and discuss that how nature of science is reflected in this subject?

Finally, they were assigned an article named “Influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science (Khishfe & Abd-El-Khalick, 2002) to discuss in class. This article was explaining and exemplifying explicit reflective NOS instruction. The aim of this article assignment was to be discussed in class to familiarize them with explicit reflective component of NOS instruction better.

After these tasks, pre pre-service science teachers were provided contextualized explicit reflective NOS instruction by means of HOS based approach. The rest of the science method course included HOS based readings, activities, and NOS integrated lesson plan preparation tasks. All these HOS context familiarizing tasks were undertaken in practice session of science method course.

3.5.3. History of science context coupled with explicit reflective NOS instruction

To contextualize science method course for more effective NOS instruction, practice session of method course utilized activities and readings including HOS components. Such that, conflicts, controversies and personalities of scientists which influenced scientists work through a discovery of a scientific concept were used to create discussion environment to clarify NOS aspects explicitly. In general each week started with a reading script including HOS example followed by lesson plan presentations. These reading scripts served as a warm up part to initiate discussion on NOS and clarify NOS concepts better. Tablo4 presented the brief description of the each reading script with targeted NOS aspects:

Table 4.Brief description of History of science scripts

Reading script	**Description of the script**	**Targeted NOS aspect**
The changes in conceptions of freezing, melting points from "Science in Action", by John Lenihan, (1990)	That script mentioned about the development of terms such as melting point, and freezing points.	Empirical NOS Inferential NOS Creative NOS Tentative NOS
Double Helix by James Watson (1968)	It was related to earlier thought about DNA, and how James Watson started to be interested in structure of DNA	Soico-cultural NOS Subjective NOS Tentative NOS
Double Helix by James D. Watson (1968):	That script was related to role of Rosalind Franklin in discovery of DNA	Socio-cultural NOS
Discovery of Current Electricity (http://learningscience.edu.hku.hk/Package.html)	The script related to two different approaches adopted by two different scientists Luigi Galvani and Alessandro Giuseppe Volta.	Subjective NOS Tentative NOS Empirical NOS Inferential NOS

Moreover, these examples gave ideas related to approaching a HOS based example regarding how to analyse an example in terms of NOS aspects, what kind of examples to include in lesson plans, and how to integrate these examples into lesson plans and their teaching. Last of all, the purpose of these examples was two folded such improving the NOS understanding as well improving NOS teaching. After each HOS based example following questions were asked to highlight NOS aspects:

I. What does this script have to do with science?
II. Which aspects do you think might have been reflected through this reading and why/how (in which ways)?

As mentioned earlier, each of these HOS reading script was followed by lesson planning activity. Lesson planning activity as whole was consisting of lesson plan preparation and presentation. Pre service science teachers were required to prepare 5 lesson plans (one for each week) on the one of the science topics selected from science and technology curricula across grade K6-8. Then, each week one volunteer participant presented his/her lesson plan to the class. Lesson planning activity provided opportunities to pre-service science teachers to engage in science curricula for NOS integration and authentic teaching experiences. Additionally, it also provided contextualized NOS learning environment enabling pre-service science teachers refine and revise their NOS views. The following part provided a detail description of lesson planning activity.

3.5.4. Description of Lesson planning activity

Lesson plan preparation and presentation was the core activity of science method course. That activity provided learning opportunities regarding NOS understanding and teaching in a contextual science method course by means of HOS approach. Pre-service science teachers were required to criticize and analyse existing curriculum to develop NOS integrating lesson plans by incorporating HOS.

While preparing lesson plans, each participant was responsible to decide what content they would include in their lesson plans. The only restriction was the content in which participants should select the science content which is relevant to the elementary science and technology curricula. Pre-service science teachers prepared five lesson plans. Each lesson plan was examined and given feedback by the course instructor one after another. That is, participants turned in their next lesson plan after getting feedback from the previous one. Feedback included revisions on how better NOS integration might have done into science content with respect to (a) NOS objectives inclusion, (b) sample questions facilitating explicit reflective NOS addressing, (c) creating more NOS based discussions, (d) assessment strategies for NOS evaluation, and (e) NOS related misconceptions. Additionally, participants were also provided with help if they needed during their lesson plan preparation.

Lesson plan preparation was supposed to give opportunities to pre-service science teachers to identify strengths and weaknesses of curricular material in terms of NOS inclusion, and then adapt curricular material to address NOS in their instruction. Additionally, practicing lesson plan preparation, through getting feedback, equipped them with ability of adapting curricular materials for NOS teaching, gave insight on how to integrate and asses NOS in an explicit reflective way.

Regarding presentation of the lesson plans, for the four weeks, one volunteer participant presented his/her lesson plans by means of microteaching in which the presenter acted as a real teacher, and others pretended like students. While presenting/microteaching the lesson plans, participants were required to address NOS in an explicit reflective manner through HOS based examples. Each presentation/microteaching of lesson plan was followed by group discussion. After each presentation of lesson plans following questions were asked as prompts to trigger discussion on NOS concepts:

I. Which NOS aspects were presented through the lesson plan presentation?
II. Do you think these NOS aspects are presented adequately?
III. How better do you think they might be reflected in lesson plan?
IV. What other aspects do you think might be included? And how?

The discussion generally involved the potential ways to better integrate NOS activities and NOS concepts into their lessons plans. Additionally, discussion provided participants with opportunities articulate meanings of various NOS aspects and to internalize these aspects.

Lesson plan presentations were expected to give opportunities of reviewing all NOS aspects in both understanding and teaching perspectives through the context based examples. That is, lesson plan presentations were aimed to serve as a contextual environment to discuss NOS aspects to refine and revise NOS ideas. For instance, participants were required to address NOS in an explicit reflective manner through HOS based examples. Thus, NOS aspects were revised and discussed through HOS and science content contexts. Additionally, through lesson plan presentations, participants were given chance to model explicit reflective NOS instruction, to analyse and evaluate their peers to NOS teaching as well as gain ideas on how to teach NOS in an explicit and reflective manner .The following Table5 illustrated the timetable of the contextual activities. All these contextualized activities except the content generic ones were implemented in 2 hours practice session of science method course.

Table 5. Outline of the contextualized activities

Week	Contextualized activities
6th week	• Contextual example: Reading exempt about changes in conceptions of freezing, melting points from Science in action by John Lenihan) • Lesson plan preparation and presentation
7th week	• Contextual example: Reading exempt from Double Helix by James Watson • Lesson plan preparation and presentation
8th week	• Contextual example: Reading exempt about Rosalind Franklin from Double Helix by James Watson • Lesson plan preparation and presentation
9th week	• Contextual example: Discovery of Current Electricity • Lesson plan preparation and presentation
10th week	• Discussion on Lesson plan preparation • Lesson plan preparation

3.6. Data analysis

The data were collected based on qualitative research methodologies. Thus, the general approach for all qualitative research data was taken. The data were analysed by using Miles and Huberman (1994) systematic approach. This approach includes writing reflective notes in passages, drafting a summary sheet, writing codes, creating patterns and themes, counting for frequency of codes, relating categories and making contrast and comparisons. Furthermore, the data analysis was constant and comparative which led to inductive and comparative analysis (Merriam, 2009, pp. 175).

3.6.1. Views of nature of science questionnaire

All pre-and post- VNOS-C responses were analysed to generate pre and post instruction profiles of participants' NOS views. The protocol outline proposed by Lederman et al. (2002) was followed for interpretation and analysis of the VNOS-C data. Additionally, volunteered participants' responses to interviews were used to elaborate their views as well to ensure validity of questionnaire. Generating the NOS views profiles included writing reflective notes in passages, drafting a summary sheet, writing codes, creating patterns and themes, counting for frequency of codes, relating categories and making contrast and comparisons based on the data analysis process proposed by Miles and Huberman(1994). Moreover, while analysing the responses to VNOS-C items, it was not assumed a restrictive one-to-one correspondence between targeted NOS tenets and VNOS-C item. It was well realized that views on particular NOS aspects could be explicated in response to various items in VNOS-C and NOS aspects were interrelated (Lederman, et al., 2002). Therefore, for each NOS aspect, participant's responses to all VNOS-C items were examined and looked for evidences for understanding of the targeted aspect. Two researchers -I as a researcher and another NOS expert independently analysed pre-post VNOS-C responses of three participants' responses. These analyses were compared, with any differences resolved through discussion. At the end, both researchers were agreed on the NOS views categories which constructed the NOS profiles of the participants for the present study. Additionally, another colleague who was experienced at NOS also independently examined all the categories which were constructed from the data gained through the VNOS-C responses for a final check as the data analysis was completed. Any disagreement was resolved through discussion, and agreement on categories was settled. Then, final categorization was formed. This process was assumed to provide peer check to ensure validation (Lincon & Gubba, 1985) Analyses of VNOS-C questionnaire results were entailed transcription and coding of the interview responses. Interview transcripts and interviewed participants were separately analysed and compared for the purpose of establishing validity. Three types of categorization were used as "informed" (I) "adequate" (A) and "inadequate" (IA). The views were categorized as either "informed" (indicating a fully developed understanding of the NOS aspect including extended examples and deeper explanations), "adequate" (indicating a developing/acceptable view but with lack of deep explanations or examples), or "inadequate" (indicating a misconception or not allinged view with contemporary sicence reforms was held by the student). The differentiation between "informed" view and "adequate" view was made based on overall NOS explanations, such as references to class activities as well their own examples, details of examples and deepness of their explanations. To assess participants' levels of NOS understanding, an evaluation criteria was constructed based on NOS literature (Akerson &Abd-El-Khalick, 2009; Akerson, Cullen, & Hanson, 2009; Lederman, et al., 2002). Following table 6 described the description of the categorization of each NOS aspects used in the study:

After completing the analysis of the NOS questionnaire, each participants NOS understanding profile was constructed through pre- and post-responses of the participants to VNOS-C. Eventually, comparison of pre and post instruction profiles views were used to track changes in participants' views of NOS across the course.

Table 6. NOS categorization schema

Categorization	Inadequate	Adequate	Informed
Tentative NOS	Recognizes scientific knowledge as accumulation of absolute, certain proven facts	Recognition of science as subject to change but this view is supported with lack of extended explanation or examples	Recognizes that all scientific knowledge is subject to change with the new evidence, advancement in technology and reinterpretation of scientific knowledge. Also supports that view with and extended explanation or examples
Empirical NOS	Fails to recognize the role of evidence to make scientific claims. Fails to differentiate science from other disciplines by means of recognizing role of the evidence	Refers to “observation” and “experiments” but lack of explanation on role of experiments and observations to get “evidence” and lack of examples to support the claim.	Considers that scientific claims should be supported with empirical – direct/indirect-evidences. Also supports that view with and extended explanation or examples
Inferential NOS	Holds the views that “seeing is believing”, and science is “what we see”, disregards the role of indirect evidence and inferences	Refers to that scientists make inferences, but lack of emphasis on the distinction between observation and inference and lack of emphasize that scientists make inferences based on observations	Recognizes that while making scientific claims, it is not possible to observe all the natural phenomena, but scientists make interpretations based on scientific evidence. Also supports that view with and extended explanation or examples
Creative NOS	Recognizes science as step-by-step procedure and disregard the role of creativity	Recognizes the role of imagination and creativity but emphasizes particularly on certain part of the scientific investigation.	Holds the views that scientist’s imagination and creativity is crucial part of their any part of investigation and have role in every stage of scientific investigation. Also supports that view with and extended explanation or examples
Socio Cultural NOS	Consider science as universal and isolated from the values and norm of culture in which it is practiced	Recognition of influence of socio-cultural values on scientific investigation but lack of claim support by extended explanations or examples.	Hold the view that science is a human endeavour and both influence and influenced by the culture in which it was practiced. Also supports that view with and extended explanation or examples
Theory & Law	Holds the view that there is a hierarchical relationship between laws and theories	Consider that theories and laws as distinct form of scientific knowledge not unable to articulate clear and extended definitions or provide examples.	Recognizes theories and laws as distinct form of scientific knowledge as equally valuable. Understands that scientific theories explain natural phenomena, while scientific laws describe observed relationships between scientific phenomena. Also supports that view with and extended explanation or examples
Subjective NOS	Recognizes scientists as objective and value free. Views different interpretations of scientist due to the lack of evidence	Understand that scientists’ subjectivity influence the development of scientific knowledge but not unable to provide clear and extended explanations or examples to support the claim.	Considers that scientist’ pre-conceptions, values, background influences the way they work and interpret data. Recognizes that the theories that scientists hold guide their scientific investigations, data interpretations etc. Also supports that view with and extended explanation or examples

3.6.2. Written Journal

The data analysis of reflection paper included writing reflective notes in passages, drafting a summary sheet, writing codes and categories regarding participants' understanding of NOS and their instructional planning of NOS (Miles & Huberman, 1994)

3.6.3. Interviews

After getting transcripts of the each participant's interviews, each transcript was reviewed to make sense of data. Thus, researcher identified unit of data in which research questions might be answered this unit of data was searched for the regularities or patterns in the whole data to create categories (Merriam, 2009, pp.176). That is categories related to participants' NOS understanding and NOS teaching had been looked for through interview analysis.

3.6.4. Lesson plans

Lesson plans were analysed to seek for evidence for participants' instructional planning for teaching NOS. Similarly lesson plan analysis included category construction, and search for patterns regarding participants' instructional planning (Creswell, 2007).

Current study adopted instructional planning for NOS teaching including three components: NOS objectives, NOS integration into activities and NOS evaluation. These components were created based on experts' opinions. The figure below represented what "instructional planning for NOS meant in the present study (see figure 1):

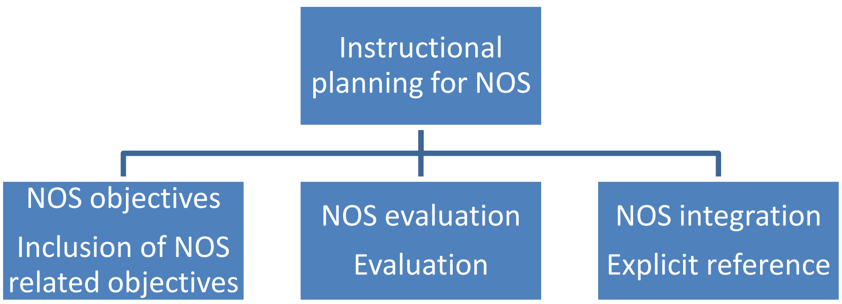

Figure 1. NOS instructional planning components

These instructional planning components (see figure1) lead the researcher while creating a rubric for lesson plan analysis. That is, lesson plan was perceived as consisting of three parts as objectives, description of activities and evaluation parts. Then each part was assesses based on inclusion of NOS components in it. Each category was constructed based on literature and expert opinion:

Objectives: In the objectives parts, inclusion of NOS objectives was categorized as:

I. Poor: No inclusion of NOS objectives referring to absence of no NOS emphasis in objectives parts and categorized as “poor”
II. Implicit NOS reference in objectives referring to non-clear, non-direct state intention of NOS objectives. These objectives were mostly subject-specific and examination of description of activities revealed the objective might related to NOS. For instance, an objective like “Students will be able to recognize different ideas of different scientists about evolution” or “Students will be able to exemplify different scientists’ views related to the generation of bacteria” categorized as “needs development”.
III. Inclusion of NOS objectives explicitly referring to inclusion of NOS objectives in objectives part, expressing an explicit intention for NOS teaching. For example, objective like “Students will be able to state that scientific knowledge can change through time by examining different views related to spontaneous generation of bacteria” was categorized as “exemplary”.

Description of activities: Participants’ NOS integration into activities was examined through three categories; No explicit reflective integration of NOS (poor); intent for explicit reflective NOS integration (NI); and explicit reflective NOS integration (exemplary). While constructing categories I kept in mind the fact that the explicit-reflective approach is an integrated approach that has basis in theory and practice. Moreover, explicit and reflective (i.e., explicit-reflective) is meant to suggest that both of these components are necessary as well as complementary (Abd-El-Khalick, 2005). Instances like having instructional objectives and not address them in instruction (explicit) or to enact instructional activities that are not aligned with some intentional objectives (reflective) is not good instructional planning and would not go far in advancing students' NOS understandings. Accordingly, the categories were created based on the fact that the most obvious sign in a lesson plan for adopting the 'explicit' component is to have one or more instructional objectives. These objectives needed to address one or more aspects of NOS explicitly that were mentioned in description of activities part of the lesson plan. Additionally, regarding reflective component of lesson plan;

the most obvious sign in a lesson plan for enacting the 'reflective' component is to have structured instructional prompts (i.e. questions, specific NOS activities) that provide students with opportunities to reflect on their activities, learning from within a NOS framework. However both components were necessary and complementary to achieve explicit- reflective approach within NOS framework (Abd-El-Khalick, 2005). Therefore, I did not analyse lesson plans separately as being explicit and reflective but as whole integrated explicit-reflective. There were three categories as “poor”, “needs development” and “exemplary” which were constructed to analyse participants’ lesson plans in terms of NOS objectives, NOS integration and NOS evaluation. Each category was constructed based on literature and expert opinion. The following table summarized the categories that were constructed while doing analysis. Then, the brief description of each category was provided below:

Table 7. Lesson plans analysis’ categories.

	Instructional planning for NOS components	**Categorization**
Objectives	Inclusion of NOS explicitly	Exemplary
	Implicit NOS reference in Objectives	Needs development
	NO explicit NOS reference in objectives	Poor
Evaluation	Reference to NOS explicitly in Evaluation part	Exemplary
	No NOS evaluation specifically	Poor
NOS integration	NO explicit reflective reference	Poor
	Intent for NOS integration : • Explicit but Direct NOS instruction • Lack of coherence between NOS objective and NOS specific instructional prompts	Needs development
	Explicit –reflective NOS instruction: • Specific NOS questions • Clear connection between NOS and science content • Coherence between NOS objectives and NOS specific instructional prompts	Exemplary

Brief description of each category:

Objectives*:* In the objectives parts, inclusion of NOS objectives was categorized as:

a) Poor (No inclusion of NOS objectives): referring to absence of no NOS emphasis

b) Needs development (Implicit NOS reference in objectives): referring to non-clear, non-direct state intention of NOS objectives. These objectives were mostly subject-specific and examination of description of activities revealed the objective might related to NOS. For instance, an objective like “Students will be able to recognize different ideas of different scientists about evolution

c) Exemplary (Inclusion of NOS objectives explicitly): referring to inclusion of NOS objectives in objectives part, expressing an explicit intention for NOS teaching. For example, objective like “Students will be able to state that scientific knowledge can change through time by examining different views related to spontaneous generation of bacteria.

Description of activities*:* Participants’ NOS integration into activities was examined through three categories; No explicit reflective integration of NOS (poor); intent for explicit reflective NOS integration (NI); and explicit reflective NOS integration (exemplary). While constructing categories I kept in mind the fact that the explicit-reflective approach is an integrated approach that has basis in theory and practice. Moreover, explicit and reflective (i.e., explicit-reflective) is meant to suggest that both of these components are necessary as well as complementary (Abd-El-Khalick, 2005). Instances like having instructional objectives and not address them in instruction (explicit) or to enact instructional activities that are not aligned with some intentional objectives (reflective) is not good instructional planning and would not go far in advancing students' NOS understandings. Accordingly, the categories were created based on the fact that the most obvious sign in a lesson plan for adopting the 'explicit' component is to have one or more instructional objectives which explicitly address one or more aspects of NOS that addressed in description of activities part of the lesson plan. Additionally, regarding reflective component of lesson plan; the most obvious sign in a lesson plan for enacting the “reflective” component is to have structured instructional prompts (i.e. questions…) that provide students with opportunities to reflect on their activities, learning, etc. from within a NOS framework. However both components were necessary and complementary to achieve explicit- reflective approach within NOS framework (Abd-El-Khalick, 2005). Therefore, I did not analyse lesson plans separately as being explicit and reflective but as whole integrated explicit-reflective. The brief description of each category was made as followings:

a) Poor (No integration of NOS): referring to ‘no efforts or emphasis related to NOS issues explicitly and reflectively.

b) Needs development (Intent for NOS integration): This category was explained by inclusion of NOS more indirectly and lack of efforts regarding to connect content with NOS or providing NOS related questions as well as lack of coherence between NOS objectives enacted in description of activities part. As mentioned above explicit-and reflective components were complementary and necessary thus, the explicit and reflective components were sought for simultaneously. To put it straight, concerning explicit NOS component; it was more related with the consistency between having objectives as well as mentioning it in description of activities part. That is, having NOS objective couple with an activity. For instance, if participant did not included any empirical NOS objectives but emphasized it in description of activities part that means it lacked of explicit component and was categorized as “needs development”. Similarly, considering reflective component; it was more related to providing structured instructional prompts within a NOS framework. For example, in an instance like, participant did not provide NOS questions, or activities that reflected how science work or did not show efforts to keep up NOS discussions, the participant failed to be reflective regarding NOS in her lesson plan.

c) Exemplary (Explicit-reflective NOS integration): This component was also examined from two perspectives as being explicit and reflective Specifically achieving explicit component in a lesson plan required to have one or more instructional objectives that explicitly address one or more aspects of NOS which was included in description of activities part as well. For example, "Students will be able to explain the difference between observations and inferences" or "Provided with several statements related to an empirical investigation, students will be able to accurately identify which statements refer to observations and which refer to inferences". Additionally if participant also mentioned observation and inference in description of activities part, the categorization was made as an exemplary regarding reflective component of lesson plan, were related to having structured instructional prompts that provide students with opportunities to reflect on their activities, learning, etc. from within a NOS framework. To continue with example on the inferential NOS (or difference between observation and inference), the lesson plan could have, for example, an instructional activity on differentiating observations and inferences". Students will be asked to list three observations they made and three inferences they derived. After group presentations, students were asked to discuss the following questions, 'What distinguishes an observation from an inference? Do we put the same level of trust in observations and inferences? Why or why not?” The categorization for reflective component of lesson plan was made as “exemplary”.

That is, if participant achieved both explicit and reflective components of their lesson plan simultaneously, then participant attained explicit reflective approach to NOS instructional planning.

Evaluation: For evaluation part two categories had been identified:

a) Poor (No NOS inclusion): It refers to ‘no emphasis to NOS in evaluation part

b) Exemplary (Inclusion of NOS): It refers to the intention to assess NOS explicitly in evaluation part.

Samples of lesson plans from each category were provided in Appendix C.

3.7. The role of the researcher

In present study I as a researcher conducted data collection and data analysis. Several cautions have been taken to ensure validity and reliability such as peer review, use of multiple data source, expert negotiations and so on. However due to the nature of qualitative research it is impossible to elimination of all researcher biases. Therefore it is important to inform the audience about the researcher background in relation to science and NOS to minimize biases.

The researcher earned her bachelor’s degree in science education from Middle East Technical University in Ankara in Turkey. After graduation, the researcher started her integrated Ph.D. program at the same university in the department of Elementary Education. At the same time, the researcher did some tutoring that she help elementary students to improve their science knowledge. During her Ph.D. program she involved in several projects included conducted in conjunction with TUBİTAK. Through that project, she involved in as a researcher and conducted workshops for in-service teachers aiming to improve in-service science teachers’ NOS views and NOS teaching practice. Additionally, through the Ph.D. program, I assisted science method courses offered at Middle East Technical University for pre-service science teachers which were highly concentrated on NOS regarding content and assessing NOS views.

The researcher believes that science is empirically based, tentative, inferential, creative, subjective and socially culturally embedded. However, I am as a researcher also aware that these tenets are not a strict list and there has been criticism and negotiation on the tentative definition of NOS among science education community. Additionally, I also believe that NOS could be learned by students if it is addresses explicitly and reflectively. Therefore, I also believe that Turkish science curricula should include NOS in a more explicit and reflective manner. That is, it should be targeted that elementary Turkish students should gained informed understanding of how science works.

3.8. Limitations of the Study

The current dissertation has some limitations due to the nature of qualitative research. First the results of the study could not be generalized. The study were undertaken through the science method course and the course limited to the context thus it could not be generalized to the other science contents. Additionally the number of the participants also limited the generalizability. Since only seven participants' NOS experiences were deeply investigated, it is hard to generalize the results to the larger samples except the ones whose credentials and academic experiences were similar to those were being investigated.

Second limitation of the study was related to the time constraints. Although participants were engaged in NOS for a whole semester, for long-lasting changes in NOS views and NOS teaching practice, learners need to engage in NOS for more time. However, in present study, participants were engaged in NOS very intensively, and they involved in an environment that that they could ask questions, reflect on their ideas without hesitation.

3.9. Trustworthiness of the study

3.9.1. Reliability

Since the data were collected based on qualitative research methodologies, the issue of reliability has been discussed from the qualitative research perspective in present section. Reliability in qualitative research deals with the consistency of the findings with data (Merriam, 2009). Creswell (2007), described reliability as stability of responses to multiple coders of data set through lenses of qualitative research. To ensure reliability various qualitative research experts suggested strategies as triangulation, peer examination, the researchers' position and audit trail (Merriam, 2009; Creswell, 2007; Lincoln & Guba, 1985). Actually, the first three strategies were used to ensure validity so; they were discussed under the heading of validity below. However, the audit trail was highlighted to fulfil reliability requirements of a study (Lincoln & Guba, 1985). Audit trail refers to describing the data collection process, the process of category formation (Merriam, 2009).Creswell (2007) also outscored the use of multiple coders to analyse data and providing external check on the coding process. In the current study two coders analysed the some portion of data regarding VNOS-C and the incongruities between researchers were resolved by negotiation and discussion. Additionally one of the colleague who was experienced at NOS studies was checked the raw data and interpretations any disagreement were resolved through discussion and negotiation. Same process was followed for the lesson plan analysis. As a result of extensive discussions and meetings the rubric for lesson plan analysis was constructed. Then, the criteria formed were check by another expert who was very experienced researcher at NOS and based on the feedback final lesson plan analysis criteria was constructed. Moreover, another colleague who was also experienced at NOS research checked the two participants' analysis of lesson plan and any disagreement were resolved through negotiation. Additionally, the thick description of data collection process coding process and code formation was provided to ensure audit trail which ensured reliability for the present study as well. Moreover, I as a researcher explicated the role of researcher above which clarified and gave clue about my standpoint as a researcher, my biases, my relationship to the topic, what approach I adopt while I was interpreting the data and what I was sensitive about the data.

3.9.2. Validity

Since the data were collected based on qualitative research methodologies, the issue of validity will be discussed from the qualitative research lenses. Although there are lots of validation definitions from various perspectives it could be concluded that validity refers to accuracy and trustworthy of findings (Creswell, 2007). Creswell concluded eight strategies to provide valid conclusions and stated at least two of them should be supplied to ensure validity (2007). These strategies are summarized as followings:

- Providing trust with participants and learning the culture by prolonged engagement and persistent observations in the field.
- Making triangulation -use of multiple and different sources, methods and theories- for providing confirmation on evidence.
- Providing external check by peer reviewing or debriefing.
- Clarifying researcher bias from the outset of the study to provide clear understanding about researcher's position, biases or assumptions that impact on the inquiry.
- Obtaining members' views of the credibility of the findings and their interpretations to judge accuracy.

- Making thick descriptions that enables to transfer information to other settings and to determine whether these findings could be transferred because of the shared characteristics.
- Obtaining external audits that examine process and product of the study to assess its accuracy. It provides a sense of the inter-ratter reliability (Creswell, 2007).

In the current study triangulation of the data collection tools was done to ensure validity. Interviews, responses to open ended questionnaires and reflection papers were triangulated. Additionally, lesson plans were triangulated with interviews conducted at the end of the intervention. These instruments were triangulated based on Patton, (1990) definition of triangulation sources in which the consistency of findings is checked by comparing information derived at different times by different means within qualitative methods to ensure validity and researcher biases. Moreover peer review was provided from another researcher who has no connection with the study to get an external check. Additionally, rich and thick description of the context and participants let readers to decide whether the findings could be transfer in other settings which lead readers about transferability of the findings.

3.9.3. Ethical considerations

Ensuring validity and the reliability of a qualitative research requires conducting investigation by concerning ethical issues. Therefore to taking into account ethical manner, the current dissertation does not involve any harm to participants in which there is no risk or issue of confidentiality. Moreover participants' names are used in any part of the study instead pseudo names will be used. However participants were be not informed about the purpose of study which could raises questions of ethics, however informing participants about purpose of study could lead change in some participants' attitude toward the lesson thus it could create some internal validity threats.

CHAPTER 4

FINDINGS

In this chapter, results are presented for each participant separately. More specifically, change in each participant's NOS understanding, each participant's NOS instructional planning, and how each participant's learning experience contributed to their NOS instructional planning development are presented as separate cases.

The first question that the current study explored was "How do pre-service science teachers' NOS understandings change in the context of explicit-reflective HOS-based approach?" The question was investigated through examining the changes in each participant's NOS views over the NOS intervention by the help of VNOS-C and follow-up interview responses By means of follow-up semi structured interviews on NOS views were used to create in-depth profiles of each participant's NOS understanding. Later, the change in each participant's NOS understanding regarding each aspect was described. Three types of categorization were used to define NOS understanding; inadequate (IN), adequate (A), and informed (I).

The second question explored "How does progress trajectory of pre-service science teachers in relation to integrating NOS into their lesson plans occur as a result of feedback in the context of explicit-reflective HOS-based approach?" The question was explicated by describing each participant's NOS instructional planning by the help of lesson plan analysis and interviews. In this part, the results were presented in sections as (a) information about each participant's general instructional planning, (b) development of NOS instructional planning regarding NOS objectives, (c) development of NOS instructional planning regarding activities, (d) development of NOS instructional planning regarding assessment, and (e) general overview about the development of NOS instructional planning.

The third question described “Which learning experiences contribute to pre-service science teachers’ ability to integrate NOS into their instructional plans?” This question was explored by the help of interviews conducted with participants.

4.1. CASE I

The first case of the study was Safa. Safa’s responses were presented under three sub-headings, namely; (1) Change in NOS understanding; which describes how her NOS understanding changed in the context of explicit reflective HOS based approach, (2) The progress trajectory in relation to integrating NOS into lesson plans, which explicates how progress trajectory in relation to integrating NOS into her lesson plans occurred as a result of feedback in the context of explicit reflective HOS based approach, and (3) Learning experiences contributing to the ability to integrate NOS into instructional plans, which explores which learning experiences contributed to her ability to integrate NOS into her instructional plans.

4.1.1. Change in NOS understanding

Subsequent section presented the participant’s NOS views on NOS aspects: tentative, empirical, inferential, creative, socio-cultural NOS, theory and law distinction, and subjective NOS. First, the participant’s views related to tentative NOS were presented.

Tentative NOS: Safa showed improvement in her tentative NOS views over the science method course. In her responses to pre-VNOS-C, she indicated that science is subject to change due to new evidence and technological improvements but she did not apply her view for the change of laws. She stated that laws were certain and never change. Thus her views were categorized as inadequate. Yet, an indication of informed view of tentative NOS was revealed in post-VNOS-C responses. In her response to post-VNOS-C, she appreciated the change of scientific knowledge in light of new evidence, which is gathered through either accumulation of knowledge or falsification of the existing one. Additionally, she exemplified her tentative NOS views in post- VNOS-C responses. Therefore, her views about tentative NOS for post-intervention were categorized as informed.

Table 8.Safa's sample statements related to tentative NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	I think this knowledge [scientific knowledge] may change in future because technology and knowledge develop. Therefore, people can find other things [new scientific knowledge] for science in the future and knowledge may change. For example, people [scientists] thought that there is no life in Mars but now, scientists develop their knowledge about life on Mars… Law is supported and proved; it never changes…
Post-VNOS-C	Informed	Science is tentative and can change in the future. There is no one truth in science…. Scientific knowledge can be supported/developed or refuted by new knowledge [evidence] … For example, the atom theories changed over time and the explanations [explanation related to the structure of atom] were changed in time.

Safa's responses to pre- and post- VNOS-C also gave some clues about her understanding related to empirical NOS.

Empirical NOS: At the beginning of the intervention, Safa revealed adequate understanding of empirical NOS, but she could not extended her view regarding the role of evidence to make claims, and gathering evidence through testable procedure. For instance, in her response, she stated that science involved experiments and observations but she did not explain the role of experiments and observations in scientific process to get evidence. Therefore, her view was categorized as adequate prior to NOS intervention in her pre-VNOS-C. In her responses to post-VNOS-C, she used the word empirical to differentiate science from other disciplines. Additionally, she stated that science explains phenomena through experiments, observations and inferences, which imply that there is a requirement of evidence in scientific claims. Therefore, her NOS view in post-VNOS-C-C was categorized as informed at the end of the study.

Table 9. Safa's sample statements related to empirical NOS revealed in pre- and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Adequate	Science is part of life. It [Science] lets us observe life through experiments, and understand things better…
Post-VNOS-C	Informed	…. [Regarding difference between science and other disciplines] science is empirically-based but other disciplines are not.… ….science explains natural phenomena through experiments, observations and inferences…

Safa's views on inferential NOS were described below based on VNOS-C and follow-up interview responses.

Inferential NOS: Safa showed adequate understanding of inferential NOS prior to NOS intervention. She was aware of that scientists make inferences, but she did not provide detailed explanations or examples. Additionally, she did not state that scientists made inferences based on observations. However, in her responses to pre-VNOS-C, she stated that scientists make conclusions based on data. For instance, in her responses to pre-VNOS-C, she stated that scientists concluded dinosaurs existence based on fossils. Although she revealed the view that science is not directly accessible through the senses, she did not explicate the role of inference in proposing scientific explanations explicitly. Therefore, her view was categorized as adequate. Yet, she shifted her view towards informed view at the end of the NOS intervention. For participants to be considered to have informed view of inferential NOS, they needed to express that natural phenomena are not directly accessible to senses. In this case, Safa stated that scientists make inferences based on their observations (see Table10 below for sample quotas).

Table 10. Safa's sample statements related to inferential NOS revealed in pre- and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Adequate	Based on traces and fossils, scientists conclude that [existence of dinosaurs]. It is the conclusion based on fossils and lots of research.
Post-VNOS-C	Informed	For example, scientists cannot do experiments about the solar system. Scientists make inferences derived from observations. [to determine existence of dinosaurs] Scientists made some research and found fossils. With respect to these fossils, they [scientists] make inferences.

Safa's analysis of VNOS-C and follow-up interviews gave clue related to her views on creative NOS.

Creative NOS: Prior to NOS intervention Safa did not recognize the role of scientists' imagination and creativity in scientific investigations. She stated that science involves only certain truths, and there is no place for imagination and creativity in science. Therefore, her view related to creative NOS was considered as inadequate in pre-VNOS-C. However, she shifted her view towards informed at the end of the intervention. As an indication of informed NOS views on creative NOS, she appreciated the role of scientists' imagination and creativity at all steps of scientific investigation, as revealed in her responses in post-VNOS-C (see Table11 below for sample quotas).

Table 11. Safa's sample statements related to Creative NOS revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	Scientists should not use [imagination and creativity], because there are certain truths in science, which are not dependent on scientists' creativity and imagination…
Post-VNOS-C	Informed	Scientists use their creativity in all parts of their investigation. They can use [their creativity] while they are making observations, analyzing data, inferring based on their observations, or making hypothesis. For instance, while constructing atom models, all scientists make inferences differently.

Next, Safa's views on socio-cultural NOS were described.

Socio-Cultural NOS: Safa's responses to pre-VNOS-C revealed inadequate view related socio-cultural NOS. For participants to be considered as holding inadequate views related to socio-cultural NOS, they needed to indicate science as a discipline detached from the norms and values of society in which it was practiced. In the case of Safa, she stated that science is universal and it should not be influenced by cultural values. Therefore, prior to the intervention, her view was categorized as inadequate. However, she shifted her view from inadequate to informed at the end of the study. That is, she recognized science as a discipline influenced by culture's norm and values and also provided an example to support her view (see Table12 below for sample quotas).

Table 12. Safa's sample statements related to socio-cultural NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	Science is universal; it should not be affected by socio- cultural values. We think that scientists are objective. Thus, scientists should not be affected [by values and norms of culture].
Post-VNOS-C	Informed	In the process of making observations, collecting data, experimenting, or reaching scientific knowledge, scientists are affected the conditions they live in. Thus, science is influenced by socio-cultural values…. For example, scientists might be affected by religious beliefs and limit themselves to conduct a research that is contradicting to his/her beliefs….

Safa's view on function of theories and laws were presented based on her responses to VNOS-C and follow-up interview.

Theory& Law: She revealed the misconception related to theory and law at the beginning of the NOS intervention. The misconception was that theory could change, but laws do not because they are proved. Therefore, her view was considered to be inadequate related to theories and laws prior to NOS intervention. She shifted her view towards informed at the end of the intervention. For a participant to be considered as holding informed view regarding theories and laws s/he needs to be able to indicate theories as exploratory and laws as descriptive, as well as both are not hierarchically related. She also recognized theory and law as different kind of scientific knowledge. She defined and exemplified them as well at the end of the study (see Table13 below for sample quotas).

Table 13. Safa's sample statements related to Theory & Law revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	Theory is a hypothesis that is supported by experiments and truths. The theory may change in future…. Law is supported and proved...Law is more reliable than theories.
Post-VNOS-C	Informed	Theory is an explanation of scientific phenomena. Theory may change over time….Law is definition of relationship between phenomena. A law may change... [regarding difference between theory and law] For example, the modern atom theory explains the properties of atom but the first law of gravitation defines the relationship between the matter and force.

Lastly, Safa's views on subjective NOS were described below.

Subjective NOS: Safa indicated inadequate subjective NOS view at the beginning of NOS intervention. To be considered as holding inadequate view related to subjective NOS, one needs to indicate that science is a way for searching truth, as well as scientists' pre-conceptions and beliefs do not influence the scientific knowledge they produce. Similar view was revealed in Safa's case. In her responses to pre-VNOS-C, Safa did not bring any explanation related to the reason for dinosaur extinction controversy but instead, she stated that scientists should reach the same results. That is, she denied that scientists might have different views related to the same phenomena. However, she shifted her inadequate view towards informed at the end of the intervention. She appreciated scientists' interpretations could diverge because of their backgrounds, perceptions, pre-conceptions, and expectations by providing detailed explanation. For instance, in her post-VNOS-C responses, she explained the reasons behind the dinosaur extinction controversy due to scientists' different backgrounds; personal traits and socio cultural conditions (see table14 below for sample quotas).

Table 14. Safa's sample statements related to Subjective NOS revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	I am not sure [regarding different kind on theories on extinction of dinosaurs]. Scientists should follow the same steps and reach the same conclusions…
Post-VNOS-C	Informed	The explanations [on the same topic] in science may differ because scientists are affected by their prior knowledge, creativity, social and cultural conditions….They interpret data differently because of these differences …For this reason, despite using the same information [data], they may disagree on a topic.

Overall, prior to NOS intervention, the participant revealed inadequate understanding on creative, socio-cultural, subjective NOS as well as theory and laws. However, she had adequate understanding on empirical and inferential NOS at the beginning of the intervention. At the end of the study, she shifted her views towards informed for all aspects of NOS.

The following section informs on firstly, Safa's progress on NOS instructional planning and secondly, the perceived sources of her development for NOS instructional planning.

4.1.2. The progress trajectory in relation to integrating NOS into lesson plans

Current section reports the participant's development related to NOS instructional planning. This section begins with information on the participant's general instructional planning, continues with the participant's development of instructional planning related to both NOS objectives and the progress of instructional planning regarding to NOS activities, as well as participant's development of instructional planning in NOS assessment. Finally, an overview on participants' progress in NOS instructional planning is presented**.** First sub section starts with information about Safa's instructional planning in general.

4.1.2.1. Information about instructional planning in general

The examination of lesson plans showed that the participant planned to teach the following topics respectively; Atom models (7^{th} grade), Solar system (7^{th} grade), Properties of matter (6^{th} grade), Electricity (7^{th} grade), and Cell division and Inheritance (8^{th} grade). All these science content are included in Turkish Science and Technology Curriculum for Elementary

Grades and the participants were free to choose any topic. Through the lesson plans, participants were responsible for including objectives part referring to their planned goals of the lesson, activities part referring to planned instructional strategies/tools to achieve their planned goals, and finally assessment part referring to the planned strategies to assess their planned goals. The participants were also asked to address NOS teaching and science content together in their plans. That is, they were expected to integrate NOS into all parts of the lesson plan, including objectives, activities and assessment. The subsequent section presented Safa's improvement regarding including NOS objectives into her instructional planning.

4.1.2.2. Development of lesson plan regarding NOS objectives

Objectives part of the lesson plan indicated whether the participants had the intention of teaching NOS explicitly or not. Inclusion of NOS objectives into lesson plan was an indication of how participant perceived teaching NOS such as whether she recognized NOS as an add-on topic or as an important issue as the other science content. Analysis of her lesson plans showed that Safa's tendency towards inclusion of NOS objectives into lesson plans were vague for the first three lesson plans. For example, **in her first lesson plan**, she stated an objective related to tentative NOS in the context of atom models. The objective she wrote did not directly address the goal related to the comprehension that science is subject to change. However, it was evident in the description of activities part that she intended to teach tentative NOS in the content of atom models. Thus, her objective related to NOS was stated to be content-specific. The objective on tentative NOS was as "Understanding the development of atom models". Other than tentative NOS objective, she did not state any NOS objectives. However, the examination of the description of activities part of the lesson plan indicated that she included instructional prompts to address tentativeness, subjectivity and inferential aspects of NOS within the *Atom models* science topic. Thus, researcher gave suggestions about inclusion of objectives on these aspects which directly aimed NOS itself.

Analysis of **second and third lesson plans** revealed unclear manner on inclusion of NOS objectives. For example**, in the second lesson plan**, she did not include any NOS objectives. **In the third lesson** plan, likewise her first lesson plan, she wrote a content specific NOS objective. She included only one objective referring to tentativeness in the content of atom models: "Notice that the thinking about atom concept changed in a time". While examining the description of activities part, one could conclude that she intended to focus on tentative NOS with this objective. Safa did not include any objective on empirical and subjective NOS but examination of the description of activities part indicated that she planned to cover empirical and subjective NOS aspects. Thus, she got notice on considering including more NOS objectives by the researcher.

The analysis of the last two lesson plans showed that participant started to include NOS objectives. **In fourth lesson plan** in which she planned to teach electricity**,** she wrote objectives that directly addressing the NOS aspects. She stated NOS objectives related to empirical and subjective NOS: “Recognize that the scientific knowledge can be obtained by observations and empirically [experiments] “and “Notice that different scientists have different scientific thought about the same topic”. **In the last lesson plan** that she planned for cell and inheritance content, she wrote NOS objectives directly focusing on the aspects. She stated NOS objectives related to subjective, tentative, and empirical NOS: “Notice that different scientists have different scientific thought about the same topic and science is subjective”, Notice that scientific knowledge can change through the time” and ““Recognize that the scientific knowledge can be obtained by observations and empirically [experiments]”.

Looking over all five lesson plans, it can be concluded that she improved herself in writing NOS objectives. In her first lesson plan, she only stated tentative NOS in objectives parts as a content specific NOS objective, although she intended to teach tentativeness and subjectivity which was revealed through examination of description of activities part. In the second lesson plan, she did not include any NOS objectives. In the third lesson plan, there were objective only on tentativeness, but she planned to teach subjective and empirical NOS as well which was inferred from the examination of description of activities part. For the last two lesson plans, in objectives parts, she started to refer science and scientist rather than being content specific which indicated her perception of NOS as separate topic to teach. In the fifth lesson plan, she stated objectives on empirical and subjective NOS. Similarly, in the fourth lesson plan, she stated empirical, subjective, and tentative NOS objectives. Looking through the frequency of NOS objectives, tentative, empirical, and subjective NOS aspects were the most stated NOS objectives among the others. The following table depicted the objectives that Safa stated in each lesson plan.

Table 15. NOS objectives in each lesson plan

# of lesson plans	Grade level	Science content	NOS aspects	NOS objective
1	7th	Atom models	Tentative NOS	Understanding the development of atom models
2	7th	Solar system	-	-
3	7th	Properties of matter	Tentative NOS	Notice that the thinking about atom concept changed in a time
4	7th	Electricity	Empirical NOS	Recognize that the scientific knowledge can be obtained by observations and empirically [experiments]
			Subjective NOS	Notice that different scientists have different scientific thought about the same topic
5	8th	Cell division and inheritance	Empirical NOS	Recognize that the scientific knowledge can be obtained by observations and empirically [experiments]
			Subjective NOS	Notice that different scientists have different scientific thought about the same topic and science is subjective
			Tentative NOS	Notice that scientific knowledge can change through the time

-: indicates the lack of the task

At the end of the NOS intervention, interview was conducted to understand the participant's perceptions on NOS instructional planning. The interview included questions related to her perception of writing NOS objectives, explicit-reflective NOS instructional planning, NOS assessment, and her teaching rationale to teach NOS. Additionally, the participant wrote a reflective journal on her perceptions of teaching NOS. Those answers were used to back up her tendency for writing NOS objectives revealed in lesson plan analysis.

According to the analysis of post interview, she believed that teaching NOS should be planned explicitly rather than as an add-on or side content. She stated that teaching NOS is as important as teaching other science content. Therefore, it should be addressed in the objectives part of the lesson plan:

R: Considering the lesson plans that you are supposed to prepare for your teaching as a teacher in the future, do you think that NOS should be explicitly stated in the objectives part of the lesson plan?

S: I think there should be NOS objectives in it.

R: Why do you think so?

S: We did not learn NOS until this course. I think, providing students with NOS concepts will help them value NOS and also NOS instruction would be more effective.

R: Let's say you will teach NOS in the content of digestion system. What do you think about writing NOS objectives in addition to the objectives related to digestion system in your lesson plan?

S: If I value NOS as important as other science content, I think I need to state NOS in objectives.

Additionally, she also pointed out on how NOS was reflected in Turkish Science and Technology Curriculum. She stated insufficient weight of NOS in the curriculum. According to her, NOS objectives should be involved in the specific science content objectives in the curriculum. By this way, science teachers can be motivated to pay attention to NOS in teaching:

R: What do you think about the inclusion and/or reflection of NOS in the curriculum?

S: I checked the objectives in the curriculum. There is a rare emphasis in NOS objectives. For that reason, I think NOS should be emphasized more in the curriculum.

R: Then, how should NOS be emphasized in the curriculum?

S: It should be embedded in the objectives part of the each specific science content. By this way, teachers might be aware of NOS more easily because we are learning NOS here but there are teachers who have no idea about NOS.

The following section described the development of participant's explicit-reflective NOS instructional planning through the activities part of the lesson plan.

4.1.2.3. Development of lesson plans regarding NOS activities

This section informed about in what ways and to what extent the participant achieved to adopt explicit-reflective approach to teach NOS. Furthermore, the kind of strategies that participants preferred to use mostly while planning to teach NOS was also notified. Analysis of the “description of activities” part of the lesson plans revealed that Safa adopted simply teacher-centered teaching approach for the first two lesson plans. However, she switched her NOS teaching approach to student-centered and explicit-reflective approach in which there were more NOS questions and stronger connections with NOS and science content for the rest of the lesson plans. **For instance, in the first lesson plan,** although she added content specific NOS objective related to tentative NOS, in her description of activities part, she addressed NOS in much more implicit way in the content of atom models. That is, in the description of activities part, she did not use any strategies to provide opportunity for students’ discussion and reflection on their ideas. . Additionally, Safa used lecture method to teach tentative NOS such that she preferred to give definition of tentative NOS directly:

“…I will say to the students [regarding atom models] that the valid model is the model that modern atom theory proposed. I will mention about all models [that] contributed to the development of the valid model and tell them that [these models] are not wrong. We use modern atom theory because it is the most developed model, and in the future if scientists find new things about the atom; this model will change.”

Researcher encouraged her to adopt more student-centered teaching strategies and to be reflective for her planned NOS teaching. The feedback given was:

“…Try to adopt more student-centered teaching strategies. To teach NOS, you could emphasis how scientists work and what science is”

Although she addressed tentative NOS in the description of activities part of the first lesson plan, and she added a content specific objective related to NOS, she did not provide any instructional prompts related to NOS. For that reason, she failed to address explicit and reflective components of tentative NOS effectively in her instructional planning. Therefore, her lesson plan regarding tentative NOS was categorized as *“needs development”.*

In the same way, she maintained her teaching approach as teacher-centered (e.g. lecture method) **for the second lesson plan**. In the second lesson plan, she did not provide any NOS objectives which indicated lack of explicit component of instructional plan regarding NOS aspects. However, in her descriptions of activity part, she planned to teach tentativeness, role of scientists’ creativity and imagination, subjectivity, and socio-cultural embededdness within the solar system science content. Likewise the first lesson plan, she maintained giving direct definitions of these aspects using lecture method. For instance, for the subjective and empirical NOS, she gave the definitions directly:

"… Science is subjective. It changes with respect to social and cultural conditions, and scientists' creativity and imagination. In our example, all scientists found something about this event [speed of light] by using their conditions and were affected by their creativity. All of these show us that science is subjective. Also, scientists say something about the speed of light by making observations, drawing inferences and conducting experiments about this event. This shows us that science is empirically-based…"

Following this lesson plan, the researcher advised her to use some NOS questions to initiate NOS discussion and create opportunities for students' reflection:

"…Through the script, you analyzed the HOS example to point out NOS aspects. It is good that you analyzed it and indicated NOS aspects. However, it is important to think about how you could teach these aspects to the students. Thus, you need to think about questions or other strategies that might be used to address NOS in that context explicitly and reflectively"

Therefore, her instructional planning regarding subjective and empirical NOS was categorized as *"poor".*

Nevertheless, while teaching tentativeness, she showed some efforts to be more reflective and to apply student-centered strategies although she did not state any objective regarding tentative NOS. Due to the absence of objective related to tentative NOS, her instructional plan was considered to be lack of explicit component. However, she showed some efforts to ensure reflective teaching of tentative NOS in instructional planning. For example, she added questions and connected HOS example related to the speed of light with NOS better, instead of giving direct definition of tentativeness as she did in her first lesson plan. She wrote that:

"….However, at the 17th century, some scientists thought that the measurement [regarding the speed of light] that was done at the 13th century was not true. The light should gain speed more rapidly than the known value. Then, they made experiments and observations to show [support] their expectations [hypothesis] and they came up with a value which was closer to the value of speed of light found in the 13th century. But the researches continued their research about the speed of light during 18th and 19th centuries and they found different values of the speed of light"

After providing the example, Safa showed efforts to connect this HOS example with NOS by providing some NOS questions:

"…What do you understand all of these explanations?", "Which scientists are right about the speed of light?" There is no absolute truth in science. Science is tentative, it changes in time and it is developed with new research, observations and experiments…"

Regarding the teaching of tentative NOS, her efforts to have explicit- reflective approach were detected. Thus, tentative NOS instructional plan was categorized as ***"needs development".***

In the third lesson plan, she planned to teach properties of matter as the science content. She planned to address tentative, subjective and empirical NOS for which she also provided objectives related to these aspects**.** In her lesson plan, she showed efforts to be more explicit-reflective and student-centered with respect to teaching these aspects. In her descriptions of activity, she used hands-on activity combined with an example from history of science to teach tentativeness. Regarding hands-on activity, she gave students an iron wire and asked them to cut that iron wire into smaller pieces as much as students could. Later, she asked the following questions related to hands-on activity, and then connected them to properties of matter topic by using HOS example:

"…I give them [students] an iron wire to answer my questions by observation. I will continue with discussing how small they can cut the wire, what they can say the length of the last part, and whether they can continue cutting even that last part under the microscope"

Then she gave an example of different kind of explanations related to the properties of matter. Then, she provided a question regarding tentative NOS:

"After listening to their different ideas about this topic [regarding different answers to provided questions], I explain that there are different opinions that were discussed through history by different scientists…. For example, Democritus said that the matter was composed of little; indivisible particles and all matter had the same particles called atom. After 50 years, other scientists showed that atoms could be separated to smaller particles. I will ask them what can be the reason of the change in scientific knowledge… By conducting new experiments and observations, scientists might change a scientific knowledge. This situation shows us that science is tentative. Scientists might change the knowledge by observations or experiments. There is not just one way to reach new knowledge. After I will mention these, I will continue with the atom models…"

Furthermore, she used phrases like below which indicated her efforts to be reflective. That is, she provided students with opportunity to think about the example and reflect on the example regarding NOS aspect:

"…I will discuss why we have different information about what the matter is composed of. I will ask them to explain the reason of having different atom models…. and 'What do you know about matter?' and 'What do you think about how they are formed?', 'Do you think that you can separate them in invisible parts?' After they [students] answer to these questions I will encourage them to discuss their different opinions about these questions…"

In addition to using hands-on activity combined with HOS example, she also tended to apply more student-centered teaching strategies, and showed efforts favoring reflective approach. That is, she added more questions and tried to create discussion environments instead of adopting teacher-centered strategies for teaching tentative NOS. Thus, her instructional plan regarding tentative NOS was categorized as "*exemplary*". However, while she was planning to teach empirical basis and subjectivity, she simply chose lecture method instead of using examples, questions or hands-on activity:

"I will say that scientists continued their research by making observations and experiments. For this reason, they [students] can understand that science is experimental based…"

For subjectivity, she planned to say:

"….it [scientific knowledge] might change from scientists to scientist because of their prior knowledge, social and cultural conditions or their creativity. Science changes from a scientist to scientist and this shows us that science is subjective…"

Researcher notified her about adopting reflective approach by using specific NOS questions targeting the planned NOS aspects:

"You should write [to address subjective and empirical NOS] which questions you will ask, and how you will integrate these questions and how you will link them to how scientist works…"

Since she provided objectives on these aspects, it was concluded that she had some efforts to adopt an explicit approach but reflective component of her plan was missing (e.g. lack of NOS related questions). Therefore, her instructional plan regarding empirical and subjective NOS was categorized as "*needs development*". **In the fourth lesson plan**, she displayed the same tendency to teach NOS with the third planning. Similarly, she planned to teach empirical basis, tentativeness and subjectivity in the content of electricity topic. She used a HOS script about electricity. In her plan, first, she wanted students to read and analyze the script regarding the targeted NOS aspects. She led students analyze the HOS script related to NOS through specific NOS questions and gave students time to reflect on their ideas. For instance, for empirical basis, for which she also provided an objective, she planned to ask the following questions to address in an explicit reflective manner:

"I will continue with discussing their opinions about the text. Firstly, I will ask them 'what can you say about how scientists develop their thinking and how they [scientists] continue making research about a topic with respect to the first paragraph?' I ask these questions to understand whether students realized that science is developed by making observations and experiments. Science is empirically-based. ….. After I listen to their [students'] explanations, I point out in paragraphs [HOS script] that all scientists make observations or experiments to develop their investigations.…"

Here, it can be detected that she kept her efforts to adopt reflective strategy and student-centered teaching strategy through asking questions, and giving students time for explanations. Therefore, her instructional plan regarding empirical NOS was categorized as "*exemplary*". However, for tentativeness and subjectivity, it seems that her plan was less successful at connecting HOS based example with these NOS aspects. Here, she gave the definition of tentativeness and subjectivity directly. Moreover, she used the same structure as she used in the third lesson plan for addressing tentative and subjective NOS:

"….After that I will ask them [following question] "did all scientists have the same opinions about the properties of electricity?'… Then, I analyze the paragraphs [pointing out relevant pieces from the text] to show them different scientists with different opinions, which indicated that the using of bottle by different scientists [referring various design of experiments for same purpose] in different ways. And I ask them 'What can be the reason of the change in scientific knowledge?' Then I will say that the science is tentative and subject to change and it might change from scientists to scientist by the effect of their prior knowledge, social and cultural conditions or their creativity. Scientific knowledge changes from a scientist to scientist and this shows us that science is subjective. By making new experiments and observations, scientists might change a scientific knowledge. This situation shows us that science is tentative."

Additionally, the researcher suggested including more NOS questions and integration ideas about other NOS aspects to achieve explicit reflective teaching of NOS. Regarding subjective NOS planning, she included NOS objective but she planned to teach it in a direct way in other words in an teacher-centered manner. Therefore, her instructional plan regarding subjective NOS was categorized as "*needs development*". For tentative NOS, she provided neither objective related to it, nor instructional prompts to ensure reflective tentative NOS instruction. Therefore, her instructional plan regarding tentative NOS was categorized as *"poor*".

Additionally, researcher also gave suggestions regarding inclusion of creativity aspect of NOS:

"It is better if you ask more specific questions. For instance; at past, scientists use different investigations about the same topic; what do you think why they make it differently –the expected answer would be due to their creativity; and then you can ask 'do you think that all scientists use their creativity during their work"

Similar to the third and fourth lesson plans, Safa planned to teach tentative, subjective and empirical NOS in addition to creative NOS which she also provided objectives related to these aspects in her **fifth lesson plan**. She planned to integrate these aspects within the content of cell division and inheritance. She used HOS based reading script on inheritance. She planned to ask students to read and analyze the reading script regarding NOS aspects. She provided some NOS specific questions to guide them to understand how the reading script reflected NOS. As similar with previous two lesson plans (third and fourth), her planned teaching for tentativeness adopted reflective and student- centered teaching strategy in which she included NOS specific questions and provided some space for students' reflection:

"…After that, I will start the lesson by giving them [students] a reading text about the development of genetic inheritance and then I will ask them 'What do you know about inheritance?' and 'What do you think about the development of inheritance theory?', 'Do you think that it is accepted with its first version? 'After they answer these questions, I ask them to read the text. Then, I will engage them with the discussion on their different opinions about these questions."…….. "After that I ask them 'Did all scientists have same opinions about the genetic inheritance?'. Then, I will point out the parts indicating different scientists' different opinions and emphasize different scientists' different thinking about inheritance. After, I ask them 'What can be the reason of the change in scientific knowledge?' Then I will say that the science is tentative and subject to change…"

Therefore, she achieved to be explicit reflective NOS instructional planning regarding tentative NOS and it was categorized as "*exemplary*". Like the fourth lesson plan, she also tended to adopt reflective and student-centered teaching strategy while she planned to teach empirical basis. She provided some specific questions and connected the HOS based example with how science works well. Therefore, her planned teaching for empirical NOS was considered to be "*exemplary".* However, the way she emphasized empirical basis were same as she addressed empirical NOS in her fourth lesson plan:

"I will continue with discussing their opinions about the reading text. Firstly, I ask them 'what do you think about how scientists develop their inferences about the topic?' After I listen to their explanations, I show them in paragraphs [the relevant parts in text] that all scientists make observations or experiments to develop their investigations. But they do not follow the same way, all had different ways. There is no only one way to reach the new knowledge…"

For the creativity and subjectivity aspects, she preferred to give direct definitions of each aspect:

"…The creativity of scientists has an important influence for developing their scientific knowledge. For this reason, there have been many different opinions about how inheritance occurs in human body"

Furthermore she reflected her mixed views for subjectivity, by giving a definition of science as tentative from scientists to scientists due to subjective nature of scientific knowledge:

"…it might change from scientists to scientist by the effect of their prior knowledge, social and cultural conditions or their creativity. Scientific knowledge changes from a scientist to scientist and this shows us the science is subjective…"

Thus, her instructional planning regarding subjective and creative NOS was categorized as *"needs development".* To sum up**,** analysis of lesson plans revealed that, Safa's tendency to teach NOS shifted from teacher-centered teaching strategies (e.g. lecture method) to student-centered teaching strategies and reflective approach. At first lesson plans, she preferred to give direct definitions of planned NOS aspects without adding any questions, or making connections with the HOS examples that she provided. However, throughout the further lesson plans, she used more questions to bring up NOS issues. Additionally, she was able to connect HOS based examples with NOS more successfully which gave opportunities for reflection of students. Distinctively, she used hands-on activity combined with HOS to teach tentativeness. Mostly, she tended to adopt teacher-centered teaching strategies. Another notable result was related to her manner for teaching tentativeness. She used different kinds of instructional strategies for teaching tentativeness such as NOS questions, HOS based examples and hands-on activity while she used mostly lecture method for teaching planned NOS aspects (e.g. empirical NOS, subjectivity, creativity etc.).

Interview conducted at the end of the study to understand participants' perception of NOS instructional planning. Interview included questions related to her perception of teaching NOS explicitly. Additionally, participant wrote reflective journal on her perceptions of teaching NOS explicitly. Although she used different kinds instructional strategies for teaching only tentativeness, analysis of interview and reflection paper also showed that she would use HOS based examples and NOS specific questions while teaching NOS in a reflective manner. For instance, during the interview she stated that she would use HOS for teaching NOS:

R: How would you teach NOS, what kind of strategies would you use to address NOS?

S: In my opinion, we can teach [NOS] through examples. I would give reading text [HOS based] or mention scientists'' lives as I did in lesson plans. Then, I would point out to the process that scientists go through while conducting scientific investigations.

Her responses in reflection paper also revealed that she tended to prefer student- centered teaching approaches and reflective manner for teaching NOS. For instance, she stated that she would plan to create a discussion opportunities on connection of NOS with the given example or reading text:

"…I plan to teach NOS in my future teaching through texts [HOS examples], which show the relationships between the scientific events and discussing NOS aspects in the classroom to get attention of students for NOS examples"

Following table16 indicated each NOS aspect she planned to teach in *activities part,* and the instructional strategies she planned to use to teach NOS:

Table 16. Summary of NOS aspects addressed in description of activities part of lesson plan

# of lesson plans	Grade level	Science content	NOS aspects	NOS teaching strategies	NOS objectives	Explicit-Reflective
1	7^{th}	Atom Models	Tentative NOS	Lecturing	✓ -	Needs development
			Tentative NOS	HOS example	-	Needs development
2	7^{th}	Solar system	Empirical NOS	Lecture	-	Poor
			Subjective NOS	Lecture	-	Poor
			Tentative NOS	Hands on activity combined with HOS example	✓	Exemplary
3	6^{th}	Properties of matter	Empirical NOS	Lecture	-	Needs development
			Subjective NOS	Lecture	-	Needs development
			Tentative NOS	Lecture	-	Poor
4	7^{th}	Electricity	Empirical NOS	HOS example	✓	Exemplary
			Subjective NOS	Lecture	✓	Needs development
			Tentative NOS	HOS example	✓	Exemplary
			Subjective NOS	Lecture	✓	Needs development
5	8^{th}	Cell division and Inheritance	Empirical NOS	HOS example	✓	Exemplary
			Creative NOS	Lecture	-	Needs development

✓ : indicated the existence of the task, -: indicated the lack of task, √- : indicated the incomplete of task

Next, participant's development in NOS assessment revealed through lesson plan analysis was presented.

4.1.2.4. Development of lesson plans regarding NOS assessment

This section informed about the kind of assessment strategies Safa used while assessing NOS aspects in her lesson plans. Analysis of lesson plans revealed that she planned NOS assessment in her all five lesson plans. Although her NOS assessment was vague in her first lesson plan, she adopted more distinct assessment strategies for the rest of the lesson plans. For instance, in her **first lesson plan,** she stated she would assess her students' NOS understanding by asking questions about the development of science. However, she did not specify any kind of questions that she would ask:

"I can assess my students' NOS understanding by using some questions about the development of science [and] I understand whether they have misconceptions about the topic [relevant NOS aspects]…"

In the second lesson plan, she showed more robust attitude towards assessing her students' NOS understanding. She chose both formative and summative assessment strategies to assess students' NOS understanding such as paying attention to students answers related to NOS questions as a formative assessment strategy, as well as assigning them NOS poster preparation as a summative assessment strategy:

"I evaluate my students [NOS understanding] by observing their discussion with other students and by paying attention to their answers related to nature of science at the end of the lesson. And I give them homework which is preparing a poster indicating the development of a scientific event by addressing the nature of science"

However, she did not apply any specific assessment strategy specific to each targeted planned NOS aspects, instead, she preferred to use more general assessment strategies. In **lesson plans 3, 4, and 5**, she adopted preparation of concept map as an assessment strategy:

"I want my students to prepare a concept map related to these lessons to mention the nature of science and their understandings about science. I detect their misconceptions with these concept maps and [I] improve their understandings"

Following table indicated the brief description of each NOS assessment strategy for each lesson plan:

Table 17. NOS assessment strategies used in each lesson plan

# of lesson plan	Science Content	NOS aspects	NOS assessment strategies
1	Atom models	Not specified	NOS questions Poster preparation
2	Solar System	Not specified	Poster preparation Students' answers to NOS related questions during the lesson
3	Properties of matter	Not specified	Concept map preparation
4	Electricity	Not specified	Concept map preparation
5	Cell Division and Inheritance	Not specified	Concept map preparation

In general, it could be inferred that she considered assessing students' NOS understanding. She used generally concept map preparation to assess students' NOS understanding. Correspondingly, post interview conducted to understand participant's perception of development regarding NOS instructional planning in terms of NOS assessment. Responses to interview also revealed that she suggested poster preparation, NOS specific questions and discourse in class as tools to assess students' NOS understanding:

R: How would you assess students' NOS understandings?

S: I would use classroom discussions of students, the questions that I ask related to NOS to assess how students perceive NOS. I think, I would do a better assessment if I assess their posters.

4.1.2.5. General overview for NOS instructional planning

In general, Safa improved her instructional planning for NOS regarding objectives, description of activities and evaluation parts of the lesson plan. Regarding objectives part, she included content specific tentative NOS objective in her first lesson plan. She did not have any NOS objective in her second lesson plan. She started to have NOS objectives beginning from the third lesson plan. Regarding description of activities part, she mostly used HOS to address NOS explicitly and reflectively. Exceptionally, she used hands-on activity combined with HOS to address tentative NOS explicitly and reflectively in the third lesson plan. She achieved explicit reflective instructional planning for empirical and tentative NOS. Additionally, regarding NOS views, she achieved informed NOS understanding for all NOS aspects over the intervention. However, she mostly addressed tentative, empirical, subjective NOS in her plans. Moreover, she only achieved explicit reflective instructional planning for tentative and empirical NOS which she also achieved informed views of these aspects. Concerning assessment of NOS in lesson plans, she did not provide assessment strategies specific to each targeted NOS aspects stated in lesson plans. However, she stated poster preparation and concept map preparation as assessment strategies to assess students' NOS understanding. Regarding consistency of her instructional planning for NOS aspects, she was consistent in her lesson plans among sections (e.g. objectives, description of activities parts and assessment parts of lesson plan) specifically for tentative and empirical NOS. That is, she provided objectives on these aspects, emphasized them explicitly and reflectively in description of activities part and also addressed them in assessment part of the lesson plan. General overview of Safa's instructional planning regarding objectives, description of activities and evaluation parts of the lesson plans was summarized in the following table:

Table 18. Summary of overall NOS instructional planning

# of lesson plans	Grade level	Science content	NOS aspects	NOS teaching strategies	Explicit-Reflective	NOS objectives	NOS evaluation
1	7^{th}	Atom Models	Tentative NOS	Lecture	Needs development	✓	✓
2	7^{th}	Solar system	Tentative NOS	HOS example	Needs development	-	✓
			Empirical NOS	Lecture	Poor	-	✓
			Subjective NOS	Lecture	Poor	-	✓
3	6^{th}	Properties of matter	Tentative NOS	Hands-on activity combined with HOS example,	Exemplary	✓	✓
			Empirical NOS	Lecture	Needs development	-	✓
			Subjective NOS	Lecture	Needs development	-	✓
4	7^{th}	Electricity	Tentative NOS	Lecture	Poor	-	✓
			Empirical NOS	HOS example	Exemplary	✓	✓
			Subjective NOS	Lecture	Needs development	✓	✓
5	8^{th}	Cell division and Inheritance	Tentative NOS	HOS example,	Exemplary	✓	✓
			Subjective NOS	Lecture	Needs development	✓	✓
			Empirical NOS	HOS example	Exemplary	✓	✓
			Creative NOS	Lecture	Needs development	-	✓

✓ : indicated the existence of the task, - : indicated the lack of task

Following section will inform on participant's perceived source of development for NOS instructional planning.

4.1.3. Learning experiences contributing to the ability to integrate NOS into instructional plans

In general, Sefıka's instructional planning for teaching NOS has been evolved in an explicit reflective manner. That is, she included NOS objectives, specific activities for teaching NOS and specific assessment strategies for assessing NOS. Researcher applied several strategies to improve participants' NOS instructional planning such as giving feedback to lesson plans, providing HOS based examples coupled with NOS which was followed by NOS discussions, and lesson plan preparations and presentations followed by NOS discussions. To understand the relative importance of these learning experiences, researcher conducted interview with participants. Analysis of interview revealed that Safa perceived lesson planning activity and HOS based examples as the main source that contributing to her ability to integrate NOS into instructional plans:

R: As a researcher, I aimed to help you improve your NOS understanding and NOS instructional planning. For this reason, I applied several strategies such as giving feedback for lesson plans, providing HOS examples in class and asking you to prepare and present lesson plans, which was followed by class discussions. Which of these activities do you think influence your skills regarding NOS instructional planning?

S: I would say lesson plan preparation first. While I was creating lesson plans, I practiced how to integrate NOS into lesson more. Therefore, I would say that lesson plan preparation contributed to my development of NOS instructional planning more. Also, the HOS examples contributed, too. I think these examples might give clue on how to integrate NOS into lesson plans.

K: How do lesson plan preparation and HOS examples contribute to your development related to NOS instructional planning?

S: Lesson plan preparation helped clarify how to integrate NOS within the flow of lesson. The HOS examples provided in class help to figure out how NOS is related with them, so I can extend these examples and teach students more easily.

4.2. CASE II

The second case of the study was named Lale. In the following, the results were outlined as ;(1) how her NOS understanding changed in the context of explicit reflective HOS based approach, (2) how progress trajectory in relation to integrating NOS into her lesson plans occurred as a result of feedback in the context of explicit reflective HOS based approach, and (3) which learning experiences contributed to her ability to integrate NOS into their instructional plans.

4.2.1. Change in NOS understanding

First, the participant's view related to tentative NOS was presented Following section will present participant's NOS views on tentative, empirical, inferential, creative, socio cultural NOS, theory & law as well as subjective NOS. Following section presented participant's tentative NOS views.

Tentative NOS: Prior to NOS intervention, Lale showed understanding of science as subject to change. However, she could not provide any detailed explanation on how change in science occurs (e.g. reinterpretation of the existing data, new evidence, etc.). Additionally, she limited the change of scientific knowledge only for scientific theories. However, she perceived laws as absolute and never change. She showed incomplete understanding of tentative NOS; therefore, her view was categorized as an inadequate view. At the end of the intervention, she shifted her view towards to informed view. As an indication of informed view of tentative NOS, she appreciated science as tentative by means of having new evidence or technological improvements for all forms of scientific knowledge. Additionally, she exemplified her view with the case of atom models (see table 19 below for sample quotas).

Table 19. Lale's sample statements related to tentative NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	inadequate	..This knowledge [scientific knowledge] may change in future for example we know that there are nine planets in our galaxy but there can be other planets that will be discovered in future… it [laws] never changes
Post-VNOS-C	Informed	..Scientific knowledge is tentative. It means, it is subject to change .New evidence or technological improvements can lead to change of scientific knowledge. For instance, atom models [indicated science's tentativeness] … Theory can change through time. Because scientific knowledge is tentative and can change through time… They [theories and laws] can also change with new information

Subsequent section described participant's empirical NOS views.

Empirical NOS: At the outset of the intervention, she revealed inadequate understanding of empirical NOS. The indication of the inadequate understanding of empirical NOS was not to be able to differentiate science from other disciplines by means of empirical NOS which was revealed by Lale. In her response, she differentiated science from other disciplines by means of easing people's life rather than requirement of an evidence, observation or testable procedures. However, she shifted her view towards to informed view at the end of the intervention. That is, she appreciated evidence as prerequisite to make claims, and support scientific explanations (see table20 below for sample quotas).

Table 20. Lale's sample statements related to Empirical NOS revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	[Regarding how science is different from other disciplines] science is more concrete and helpful for people; in science, one [scientists] could find a medicine which is useful for people.
Post-VNOS-C	Informed	[regarding how science is different from other disciplines] Scientific knowledge is supported by evidence in other disciplines knowledge do not need to be supported by evidence…

Participant’s inferential NOS views were presented below.

Inferential NOS: Lale revealed adequate understanding of inferential NOS at the outset. Her responses to pre-VNOS-C revealed that she was aware of scientists made inferences. Although she did not refer “making inferences” directly, she indicated that scientists get some ideas based on evidence in her responses. For instance, in her responses on how scientists decided on the appearance of the dinosaurs, she mentioned that scientists got some ideas on the appearance of the dinosaurs based on the fossils and bone structures. Thus her view was categorized as adequate view. She shifted her view towards informed view at the end of the study. She revealed the understanding that the natural phenomena were not directly accessible to the human senses. She articulated that, scientists made inferences based on observations and she exemplified her view (see table21 below for sample quotas)

Table 21. Lale’s sample statements related to inferential NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Adequate	[to decide appearance of dinosaurs] They [scientists] observe fossils again, [and] their bone structure and bone shape. Therefore they [scientists] can obtain some ideas about now dinosaurs looked. [to decide existence of dinosaurs] They [scientists] examine fossil traces and their genes, and they conclude that dinosaurs really existed.
Post-VNOS-C	Informed	[to decide existence of dinosaurs] Scientists investigate some dinosaur fossils. They [scientists] have done some observations [and] inference and experiments on the bones of dinosaur. They conclude that dinosaurs really existed. …Scientists create models [scientific models] based on their observations, inferences, predictions and experiments, like atom models…

Following section displayed participant’s creative NOS views.

Creative NOS: Lale indicated inadequate understanding of creative NOS at the beginning of the intervention. To be categorized as holding inadequate creative NOS view, one needed to express that scientists seek for the "true" results and they are objective. Thus, involvement of creativity would hinder obtaining "true" results and impair scientists' objectivity. In Lale's case**,** she did not recognize the role of scientists' imagination and creativity in development of scientific knowledge due to the reason that scientists' objectivity would be damaged. However, at the end of the study, she shifted her view towards informed view. She revealed the appreciation of role of scientists' imagination and creativity at all stages of scientific investigation and for the fulfillment of the missing information (see Table22 below for sample quotas).

Table 22. Lale's sample statements related to Creative NOS revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	…. for being a scientist, they [scientists] should be objective .They [scientists] should assess results truly and objectively. With imaginations, they [scientists] cannot yield true answers.
Post-VNOS-C	Informed	They[scientists] use their creativity for combining the remains of dinosaurs……They have done some observations, predictions and inference by looking fossil records then they reach some conclusions by using their creativity. Scientists use their creativity in every step of science scientific investigation. …They [scientists] use it [imagination and creativity] while they are doing observations, inferences or designing experiments.

Participant's views on socio cultural NOS explained below.

Socio-Cultural NOS: At the outset of the intervention, she showed inadequate view on socio cultural NOS. She perceived science as free of social and cultural influences. For instance, in her responses she expressed that science was universal. However, she shifted her view towards informed view at the end of the study. She appreciated the influence of cultural values and norms on development of scientific knowledge via detailed explanation and example (see Table23 below for sample quotas).

Table 23. Lale's sample statements related to Socio-cultural NOS revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	…Science is universal because we live in same world, for example laws for the nature are not change by people to people. They are not affected by social political and philosophical values….
Post-VNOS-C	Informed	Scientific knowledge can be affected by social cultural values. Because scientists' knowledge can be shaped by his/her experiences and beliefs. Problems of society in which scientists live affect their work. Because scientists did some research to solve these problem. For instance, pig flue [A(H1N1) virus] is on agenda nowadays, so scientists are working on it [pig flu virus] more intensely to solve the problem.

Following section presented participant's views on function of theories and laws.

Theory & Law: At the beginning of the intervention, Lale showed inadequate view of theories and laws. She believed that there was a hierarchical order between theories and laws and theories became law after they were proved. Yet, she shifted her view towards informed over the science methods course. She explained the role and functions of theories and laws, and gave detailed explanation on theories and laws. She expressed laws as descriptive in nature and theories as explanatory in nature. Additionally, she supported her explanation with an example on the case of atom models and Newton's Law at the end of the NOS intervention (see table24 below for sample quotas).

Table 24. Lale's sample statements related to Theory &Law revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	f the scientists concludes that his/her hypothesis is true with experiments' this hypothesis becomes theory. …..If theories are proved, this theory becomes a law and it never changes…
Post-VNOS-C	Informed	Theory is explanations about observable phenomena. Theory can change through time. …Law is the information that states the relationship between observable phenomena. They can also change with new information … For example atom theories give examples [explanation] related to structure of an atom. But Newton's law give [indicate] relationship among force mass and acceleration.

Subjective NOS: Lale held inadequate view of subjective NOS at the beginning of the intervention. Participants holding inadequate conceptions of subjective NOS believed that scientists' investigations are neutral, and their personal beliefs, pre-conceptions, assumptions do not influence the scientific knowledge they produce. For instance, Lale indicated that the reason behind the controversy of dinosaur extinction is the only long time period of after the event occurred. However, she shifted her understanding towards informed view of subjective NOS. That is, she was able to articulate that scientists' interpretations would vary because of personal backgrounds, perceptions, pre conceptions and expectations by providing detailed explanation at the end of the NOS intervention. For instance, she explained the dinosaur extinction controversy due to the scientists' background, and different pre-conceptions of the scientists (see table25 below for sample quotas).

Table 25. Lale's sample statements related to Subjective NOS revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	[regarding extinction of the dinosaurs]There are a lot of reasons such as volcano, exposure to earthquakes and separation of continents for extinction of living things. Because this events occurs 65 millions of years ago scientist could not sure about the reason of extinction of dinosaurs….
Post-VNOS-C	Informed	Scientists could interpret same data differently. Their [scientists'] background, their field of study, preconceptions might influence their interpretations. For instance, scientists studying mainly in geography might think dinosaur extinction due to continental drift while astrophysics might think that extinction due to meteor hit…

Participant revealed inadequate understanding on tentative, empirical, creative, subjective, socio cultural NOS and theory & laws prior to intervention. Lale showed adequate understanding on inferential NOS at the beginning of the intervention. She shifted her NOS views towards informed view for all aspects of NOS at the end of the study.

Following section will inform on participant's progress on NOS instructional planning and the sources of her development for NOS instructional planning.

4.2.2. The progress trajectory in relation to integrating NOS into lesson plans

Current section presented participant's improvement for NOS instructional planning. It was outlined as; general information on participant's instructional planning, development of instructional planning related to NOS objectives, development of instructional planning related to NOS activities, development of instructional planning related to NOS assessment and finally, overall development of NOS instructional planning. Next sub section started with general information about Lale's instructional planning.

This section begins with information on the participant's general instructional planning, continues with the participant's development of instructional planning related to both NOS objectives and the progress of instructional planning regarding to NOS activities, as well as participant's development of instructional planning in NOS assessment. Finally, an overview on participants' progress in NOS instructional planning is presented**.** First sub section starts with information about Safa's instructional planning in general.

4.2.2.1. Information about instructional planning in general

Participant handed in five lesson plans. She planned to teach science content such as atom models (grade7) in her first lesson plan, solar system and space (7^{th} grade) in her second lesson plan, natural selection and evolution (8^{th} grade) in her third lesson plan, bacteria (8^{th} grade) in fourth lesson plan, and buoyancy (grade 8) for the last lesson plan. She chosen all the science content that she planned to teach from Turkish science curricula which was available online. It was her responsibility to choose any science content from curricula and adapt or modify it to address NOS explicitly. While creating lesson plans, she was in charge with the writing of objectives part of the lesson plan in which she stated the planned goals of her lesson, description of activities parts in which planned instructional strategies, tools were described to achieve the planned goals and lastly, evaluation part of the lesson plan, in which planned strategies were described to evaluate the planned goals. Since all participants were required to teach NOS in their lesson plans, all were expected to adapt and design lesson plans in which they address NOS explicitly. Following section presented Lale's development with regarding to writing NOS objectives.

4.2.2.2. Development of lesson plan regarding NOS objectives

Objectives part of the lesson plans were more related with whether participants had the intention of teaching NOS explicitly/consciously. Inclusion of NOS objectives mostly indicated how they perceived teaching NOS, for example, they recognized NOS as an ad-on, topic or as an important issue as the other science content to be taught/planned explicitly. Analysis of the lesson plans showed that Lale included objectives related to NOS in all lesson plans. However, the objectives in first three lesson plans were more subject /content specific. She wrote objectives related to science content not directly to the NOS, but some NOS aspects were implied to be NOS objectives, were interpreted based on the examination of description of activities part. That is, she did not state the objective in a way that gave the idea of how science works. For instance **in her first lesson plan** in which she planned to teach *atom models*, she included an objective interpreted as targeting tentative NOS: "Students will be able to differentiate that ideas related to atom structure have changed through history" Here, she did not state objective in a way that expresses an aim addressing science is tentative. However, examination of description of activities revealed that she included instructional strategies to teach tentative NOS. She adopted same approach regarding writing NOS objectives for her second and third lesson plans. In **her**

second lesson plan she planned to teach solar system and space. She included objective on tentative NOS which was also subject/content specific such as: “Students will be able to differentiate that ideas related to formation of universe have changed through history”.

Although she mentioned subjective and creative NOS in description of activities part of the lesson plan, she did not provide any objectives on these aspects. Thus researcher alerted her to think about NOS in her objectives part of the lesson plan:

“Think about why you write objectives; do you think all these objectives cover what you intent to teach through the lesson; think about including objectives on NOS (feedback given to the 2nd lesson plan)”

Similarly, she kept content specific NOS objectives in her **third lesson plan**. She included two NOS objectives in the context of natural selection and evolution which were inferred to be objectives on subjective and tentative NOS such as: “Students will be able to recognize different ideas of different scientists about evolution” and “Students will be able to identify that ideas related to evolution changed throughout time”. Since she kept her manner of subject/content specific NOS objectives, she got feedback on being precise on NOS objectives. In her **fourth lesson plan**, she planned to teach bacteria as science content. She included NOS objectives on tentative, empirical and creative NOS. She revealed vague manner of NOS objectives. That is, she both had content specific NOS objectives and NOS objectives addressing NOS directly. Regarding content specific NOS objective, she included objective regarding creativity in the context of “generation of bacteria” which was “Students will be able to exemplify different scientists’ views related to the generation of bacteria”. Therefore, she was alerted on writing objectives directly targeting creative NOS: “If you want to teach creativity you can add an objective on it e.g. State the role of scientist’s creativity in development of scientific knowledge (feedback given to the 4th lesson plan)”

Distinctively, she wrote objectives directly addressing tentative and empirical NOS such as “Students will be able to state that scientific knowledge can change through time by examining different views related to spontaneous generation of bacteria” and “Students will be able to identify that experiments are not only route of getting scientific knowledge”. Additionally, she included all NOS aspects in objectives part that she mentioned in synopsis of the lesson plan. In her **fifth lesson plan,** she kept having objectives directly addressing NOS. She wrote objectives on creative and empirical NOS: “Students will be able to state the role of creativity in development of scientific knowledge (creativity aspect of NOS)” and the objective related to empirical NOS was: “Students will be able to state the role of observations and experiments in development of scientific knowledge (empirical-based aspect of NOS)".

In general, analysis of all five lesson plans indicated that she developed more consistent manner of including NOS objectives in her lesson plans. Although her first three lesson plans included mostly content specific NOS objectives, for the last two lesson plans she included NOS objectives directly targeting certain NOS aspects. Looking through the frequency of NOS objectives, tentative NOS was the most stated one among the others. The following table 26 indicated the objectives that Lale stated in each lesson plan:

Table 26. NOS objectives in each lesson plan

# of lesson plans	Grade level	Science content	NOS aspects	NOS objective
1	6th	Atom models	Tentative NOS	Students will be able to differentiate that ideas related to atom structure have changed through history
2	7th	Solar System and space	-	-
3	8th	Natural Selection and evolution	Subjective NOS	Students will be able to recognize different ideas of different scientists about evolution
			Tentative NOS	Students will be able to identify that ideas related to evolution changed throughout time
4	8th	Bacteria	Tentative NOS	Students will be able to state that scientific knowledge can change through time by examining different views related to spontaneous generation of bacteria
			Empirical NOS	Students will be able to identify that experiments are not only route of getting scientific knowledge
			Creative NOS	Students will be able to exemplify different scientists' views related to the generation of bacteria
5	8th	Buoyancy Force	Empirical NOS	Students will be able to state the role of observations and experiments in development of scientific knowledge

-: indicated the absence of the subject

Interview was conducted at the end of the intervention to understand participants' teaching perception of NOS and perceived NOS instructional planning development. Interview included questions related to participants' perceptions of NOS objectives, and rationale to teach NOS. Additionally participant wrote reflection paper on her perception of NOS teaching. Analysis of interview and reflection paper also revealed her manner on NOS objectives. Although she included somehow NOS objectives in her lesson plans, she stated that she did not consider herself as efficient. However, she explicated that NOS objectives should be written since NOS would increase students' interest of science in interview:

R: How could you describe your development regarding writing NOS objectives?

L: I do not think that I improved them [writing NOS objectives]. I already made mistakes on my first three lesson plans; I tried to change something on my fourth lesson plan. That is, I constructed the lesson plans in a way that students will define subjectivity separately but I am not sure whether it is true or not. I do not think that I made progression about writing NOS objectives…While preparing a lesson plan, firstly we write objectives. I remember that it was lack in my lesson plan. At the beginning we did not write objective about NOS aspects, maybe at the beginning we did not pay attention very much (on NOS).Later, in your feedbacks, you said that we should have objectives on the evolution and NOS aspects. At least, it had such an impact in this way. I learned in the course that we should evaluate NOS and should take it as an objective

R: Considering the lesson plans that you are supposed to prepare for your teaching as a teacher in the future, do you think that NOS should be explicitly stated in the objectives part of the lesson plan?

L: Like I said before, students can be guided about how the scientific knowledge is produced; it may help students love science by providing the application of science in their daily life. Therefore, (NOS) it can be emphasized more.

Although her confusion on writing NOS objectives, she was aware of how NOS was reflected in Turkish science education curriculum. In reflection papers and interview, she pointed out that insufficient of NOS objectives were addressed insufficiently:

Objectives related to NOS aspects are written in the curriculum. But I do not think that they are adequate. Especially in some parts of units there is any objectives related to NOS aspects. They should be developed (reflection paper)

The following section described the development of participants' explicit-reflective NOS instructional planning through the activities part of the lesson plan.

4.2.2.3. Development of lesson plans regarding NOS activities

That section of the "Results" part informed about in what ways and at what extent the participant achieved to adopt explicit reflective approach to teach NOS in the lesson plans/creating lesson plans. For instance, in her **first lesson plan,** she planned to teach atom models (6^{th} grade) as a science content. She covered tentative NOS in her lesson plan. She included NOS objective on tentative NOS and addressed it also in the description of activities part. She adopted an explicit approach of teaching it. Regarding reflective component of her instructional planning, although she benefited from history of atom models very briefly, she did not use this opportunity to create an environment for students discuss and reflect on their ideas. Instead, she directly planned to mention change of theories. Thus, she relied on lecturing (direct teaching) rather than connecting the HOS example with NOS, and providing NOS questions to initiate NOS discussion environment. Therefore her planned teaching was lack of reflective component of NOS instruction. Thus, her plan was categorized as *needs development* regarding tentative NOS instructional planning. The sample parts of her lesson plan which reflecting her manner of teaching NOS was as following:

"…I will define the atom as building blocks of matter. After that, I will mention Dalton, Thomson, Rutherford and Bohr Atom Models. I will say that as the time goes, the ideas related to atom structure has changed. I will ask students that what characteristic of nature of science is related to changing of ideas of atom structure through history..."

The second lesson plan was related to Solar system and space (7^{th} grade) science content. She planned to address tentative, creative and subjective NOS. She only included tentative NOS objective, although she mentioned all three NOS aspects in description of activities part of the lesson plan. In that sense, her instruction was not completely explicit regarding creative and subjective NOS instructional planning. Similar to first lesson plan, she compared different scientists' views on formation of universe, but she did not use any HOS based example to address NOS. Instead, she directly mentioned the aspects through lecturing. That is, she gave direct definitions of tentative and subjective NOS:

"… I will mention some scientists' views about the formation of universe. I will say that Newton had claimed in 1600s that universe has no starting point. According to this claim the universe exists since the infinity and it will preserve its structure to the infinity. However, George Lemaitre had stated that universe has a starting point and it expands consistently in 1927. The last studies of scientist support George Lemaitre's claim. I will say that as you notice as the time passes knowledge about the formation of universe had changed and it shows the tentative aspect of nature of science. In addition these views are partly based on scientists' imagination and prior knowledge. This shows the subjectivity aspect of nature of science…"

Since Lale kept her approach for teaching these aspects through lecturing as in first lesson plan. Thus, her lesson plan was lack of reflective component of those NOS aspects due to addressing it through lecturing and lack of NOS questions and discussion opportunities. Therefore her plan was categorized as *needs development* for teaching subjective and creative NOS aspects. Additionally, she was alerted by the researcher on providing more NOS questions and showing efforts to create discussion on NOS such as: "...Think about questions and strategies to foster students' understanding of NOS. Try to use more student-centered and try to create discussion on how scientists work..."

Third lesson plan included natural selection and evolution (8^{th} grade) as a science content. She planned to teach subjective, tentative and creative NOS. Yet, she provided NOS objectives only for tentative and subjective NOS. Thus, instructional planning for creative NOS was not exactly explicit. Regarding the way she addressed creative NOS in her plan, she started her planned lesson with hands on activity, but she did not connect that activity with any NOS aspects. Following sample from her lesson plan illustrated her manner of NOS instructional planning:

"…Then I will apply an activity that is related to natural selection. I will give students 20 red and 20 blue beans and want them to mix beans and select 10 beans randomly. Then I will ask them the numbers of blue and red beans that they select. Then students discuss that why they get different numbers of beans I expect them to relate this activity with natural selection. I am planning to motivate them by asking questions: "do you think that in nature genotypes of organisms are formed like that?" and "What can be the relationship between the selections of beans with the natural selection of organism…?"

Therefore, her plan regarding creative NOS was lacking of reflective component as well. For that reson, her lesson plan regarding creative NOS was categorized as *needs development*. Moreover, she also addresses creative and subjective NOS together with the help of HOS example on Darwin's and Lamarck's theories on evolution:

"….After they read text, I am planning to talk about differences between Darwin's and Lamarck's ideas. After I mention details I am planning to ask why scientists have different views about the evolution. What can be the reasons of these different kinds of claims? With doing this I am planning to create discussion environment for learning the ideas of students related to subjectivity and creativity aspect of nature of science…"

Here, regarding subjective NOS, she both provided an objective and also planned to emphasize it explicitly through a HOS example via discussion. That is, she planned to create a discussion on subjective NOS via different evolution theories and she provided some NOS specific questions. Therefore, she fulfilled explicit reflective instructional planning regarding subjective NOS and categorized as *exemplary*.

To address tentative NOS she used the differences of Lamarck's and Darwin's' theories of evolution. Then she provided questions to emphasize tentative NOS. She achieved to connect HOS example with NOS and created discussion environment to utilize students' understanding of tentative NOS in her plan. Following incident from her lesson plan reflected her manner of NOS instructional planning:

"I will mention Lamarck's and Darwin's theories related to evolution. I will tell that firstly Lamarck's arise in 1809 and after that Darwin's theory arises in 1859.I will say that Lamarck believes transmutation of species; on the other hand, Darwin believes common ancestor. Lamarck thinks that organisms do not have common ancestor, they turn into each other in a linear way and the complexity of organisms increase. Darwin thinks that all living organisms have a common ancestor. I will say that today Darwin's theory is the most acceptable one. I am going to ask why the Darwin's theory is most acceptable one today. Why Lamarck's theory is rejected? Is scientific knowledge can change throughout out time? What aspect of NOS is related to the changing of scientific knowledge?"

Regarding tentative NOS, she both provided objective and instructional prompts as well. For that reason, her plan for tentative NOS included both explicit and reflective components. Therefore, it was categorized as *exemplary* for tentative NOS instructional planning. **In fourth lesson plan**, she planned to teach Bacteria (5th grade) as a science content and covered tentative, creative and subjective NOS. In her lesson plan, she mentioned three kinds of experiments related to Bacteria in history. She gave a script to the students on three experiments done by three different scientists at past:

"….Then I will mention that bacteria were first seen by Anton Van Leuwenhoek (1673) with the discovery of microscope. In these times, it is believed that some of these bacteria reproduce spontaneously. I will give a text related to the experiments of three different scientists. In these years, bacteria were called as small animals…"

Then, she asked questions to initiate NOS discussion. First, she provided questions related to reading script then, she added questions related to subjective NOS such that: "What did scientist do for supporting their ideas?", "Did they do some experiments?" and "Do all of the scientists do experiments for their study". Providing HOS based example, NOS specific questions, to create NOS discussion environment and giving space for students to express their ideas on subjective NOS, made her instructional planning have reflective component of her NOS teaching. Additionally, she stated empirical NOS in objective part as well. Therefore her plan regarding subjective NOS categorized as *exemplary*. Similarly, for teaching tentative, she used same example. She added some questions to make students think on how scientific knowledge changes such as: 'Did ideas related to spontaneous generation change as the time passes?", "What can be the causes of this change?", and "Which NOS aspect is related to the changing of the theory of spontaneous generation?". Having instructional prompts specifically addressing tentative NOS, and also stating it in objective part fulfilled it as *exemplary* concerning tentative NOS instructional planning.

In the same vein, she used same HOS example and also provided some questions to initiate NOS discussion to address creative NOS. The NOS questions she used were: "Did Spallanzani and Needham share the same ideas related to spontaneous generation?", "Why did Spallanzani and Needham think differently?" What can be the reasons? And "Spallanzani and Needham did approximately same experiment. However they reach different conclusions. What can be the reasons of this"? However, for teaching creative NOS she did not connect HOS example with creative NOS. She only provided some questions alleged to trigger students' thinking on creative NOS. Yet, she provided an objective on creative NOS, revealing her intention to teach it. Therefore her instructional plan regarding creative NOS teaching was categorized as *needs development*.

She addressed Buoyancy Force as science content in her **fifth lesson plan**. She included empirical and creative NOS in description of activities part. She also stated objectives of creative and empirical NOS. In that sense, she provided explicit instructional planning for empirical and creative NOS. Lale used HOS based examples. In current lesson plan, she provided a reading script on Archimedes and provided some questions to emphasize targeted NOS aspect. The sample of script was as following:

"……After mentioning these I will give a text about Archimedes who suggest the idea of lifting force of liquids. I will want them to read the text below. Then I am planning to ask these questions to mention some NOS aspects. I ask these questions for emphasizing creativity: Why did Archimedes find lifting force while any other scientist did not? Did his creativity affect his study related to lifting force?, and Did scientist use their creativity and imagination during their investigations?"

Although her questions were more straight forward and insufficient to lead students to refine their ideas on creative NOS, participant still showed efforts to provide instructional prompts to cover creative NOS. In that sense, her instructional plan regarding creative NOS had a reflective component and therefore categorized as *exemplary* regarding creative NOS instructional planning.

In the same way, she used same HOS example to emphasize empirical NOS. She provided questions related to script and then connect the HOS script to empirical NOS, which ensured reflective instructional planning for empirical NOS. Since she stated an objective on empirical NOS and the specific instructional prompts, her instructional planning regarding empirical NOS was categorized as *exemplary.* See the specific questions she provided for teaching empirical NOS below*:*

"What did Archimedes do for supporting his idea?

Did he do some experiments?

Do all of the scientists do experiments for their study?

Is experimentation only route of getting scientific knowledge?"

Additionally, she stated that she would wrap up NOS regarding empirical and creative NOS, after the discussions provided via questions:

………According to their answers I will mention that scientist's creativity affect their investigations. In every step of science process skills, scientists use their creativity such as while making observations, inferences, predictions, experiments even collecting data they use their creativity. Because different scientist may focus on different data and their interpretations may be different. Then, I will talk about that for supporting his idea Archimedes made an experiment. However, all scientists do not use experiments while getting scientific knowledge. In some cases, doing experiment may not be possible.

Therefore, they can use their observations, inferences and predictions for getting scientific knowledge…"

In general, she improved her instructional planning regarding NOS teaching. She shifted her teaching NOS instructional plan from direct teaching of NOS with lack of explicit and reflective components towards explicit reflective NOS instructional planning. She started to use specific NOS questions. In her lesson plans, NOS objectives starting from third lesson plan. She used HOS as a context to emphasis NOS mostly. Specifically, she achieved explicit reflective NOS instructional planning starting from third lesson plan with the focus of subjective, empirical and tentative NOS. Additionally, tentative and creative NOS were the most used aspects in description of the activities part. Following summarized the instructional strategies and NOS aspects she used in description of activities part of the lesson plan:

Table 27. Summary of NOS aspects addressed in description of activities in lesson plan

# of lesson plan	Grade Level	Science content	NOS aspects	NOS teaching strategies	NOS objectives	Explicit-Reflective
1	6th	Atom models	Tentative NOS	Lecturing	✓ -	Needs development
2	7th	Solar System and space	Subjective NOS	Lecturing	-	Needs development
			Tentative NOS	Lecturing	✓ -	Needs development
			Creative NOS	Lecturing	-	Needs development
3	8th	Natural Selection and evolution	Subjective NOS	HOS example	✓ -	Exemplary
			Creative NOS	HOS example	-	Needs development
			Tentative NOS	HOS example	✓ -	Exemplary
4	8th	Bacteria	Tentative NOS	HOS example	✓	Exemplary
			Creative NOS	HOS example	✓	Needs development
			Subjective NOS	HOS example	✓ -	Exemplary
5	8th	Buoyancy Force	Empirical NOS	HOS example	✓	Exemplary
			Creative NOS	HOS example	✓	Exemplary

✓ : indicated the existence of the task, -: indicated the lack of task, √- : indicated the incomplete of task

At the end of the NOS intervention participants was interviewed and wrote reflection paper related to their NOS teaching perceptions and perceived development of their NOS instructional planning. Analysis of reflection paper and interview also supported her manner of NOS instructional planning. When she asked how she would teach NOS, she stated she would teach NOS explicitly via questions in the context of HOS in her responses to both interview and reflection paper. Additionally, during the interview she also stated that she would teach NOS as integrated to the science content:

L: I thought that just like we do in the lesson plan, within the science content, through telling students that this scientist invented this, the other invented this and asking students so what shows this to us and waiting for their response and at the end explaining that “this shows us that”. In this way I think that it should be taught explicitly…But while teaching students, by asking many questions, we should encourage them to think about NOS. I thought that I would have problems about teaching of creativity because I did not know what type of questions to ask. In my last lesson plan, I focused on creativity and asked some questions.

In her reflection paper, she wrote that she would address NOS explicitly:

“Yes, I am planning to teach NOS aspects explicitly. I am planning to ask questions related to NOS aspects and I want students to think about them”

Next, participant’s development in NOS assessment revealed through lesson plan analysis was presented.

4.2.2.4. Development of lesson plans regarding NOS assessment

That part of the results section informed about Lale’s efforts to evaluate NOS aspects that she planned to teach. The kind of strategies that she used for each specific targeted NOS aspect was reported. For instance, **in her first and second lesson plan**, she did not consider assessing NOS. Thus she was alerted on thinking about NOS assessment by the researcher: “How do you plan to assess students’ understanding of NOS on targeted NOS aspects? “Analysis of lesson plans indicated she adopted NOS assesment approach after third lesson plans. However none of the assessments that she planned to make were specific to each NOS aspect targeted to teach. **In third, fourth and fifth lesson plans**, she kept same manner of assessing NOS. She did not provide any questions specific to targeted NOS aspects. However, she emphasized NOS assessment as stating that she would ask NOS related questions. Additionally, she also took formative assessment into consideration and emphasized students' performance during discussions which revealed in her lesson plans:

"I will evaluate students according to their performance during the lesson. I mean based on their participation of discussions in the class. Also I am planning to ask a question what we learned related to NOS? Which aspects did we cover? I will assess their NOS understandings related to the participations of these questions…"

In general, Lale adopted the idea of NOS assessment after the third lesson plan. Additionally, she combined formative and summative assessment. However, she did not provide specific NOS assessment for each targeted NOS aspect. For example, in the fourth lesson plan, she mentioned creativity explicitly and reflectively in description of activities part as well as in objectives part of lesson plan. However, in evaluation part of lesson plan, she did not provide any specific assessment strategy for creative NOS. Instead she stated she would ask NOS questions.

Correspondingly, interview conducted at the end of the NOS intervention to understand participants' NOS teaching perception and their development for NOS instructional planning. Responses to interview also supported her manner of assessment showed in third, fifth and fourth lesson plans. Although she preferred to use questions as an assessment strategy for students' NOS understanding, she explicated lack of her knowledge on alternative NOS assessment strategies:

L: At the beginning, I did not have much idea about the assessment of NOS. Later, I thought that at the end of the lesson, questions related to NOS aspects that have been taught can be asked to assess how much they understand. I think that is a good method but I do not know the alternative methods because of that I do not feel myself competent very much.Following table indicated the brief description of each NOS assessment strategy for each lesson plan:

Table 28. NOS assessment strategies used in each lesson plan

# of lesson plan	Science content	NOS aspects	NOS assessment strategies
1	Atom models	-	No NOS assessment
2	Solar System and space	-	No NOS assessment
3	Natural Selection and evolution	Not specific to NOS aspect	General NOS questions Students' performance
4	Bacteria	Not specific to NOS aspect	General NOS questions Students' performance
5	Buoyancy Force	Not specific to NOS aspect	General NOS questions Students' performance

Subsequent section presented an overview of the participant's development regarding NOS instructional planning.

4.2.2.5. General overview for NOS instructional planning

Generally, the analysis of lesson plans revealed Lale's development in her NOS instructional planning regarding NOS objectives, NOS activities and NOS assessment. She started to include NOS objectives that she also mentioned these NOS aspects in description of activities part. Moreover, she showed effort to be more student centered for NOS in description of activities part. That is, she included NOS questions and planned to give more space to students to express their ideas on science. In sum, her approach for planning NOS was shifted from lecturing to more explicit and reflective manner. She achieved explicit reflective NOS instructional planning for empirical, tentative, subjective and creative NOS. Regarding her NOS understanding, Lale achieved informed understanding of all NOS aspects mentioned in the study. However, she only tried to address creative, empirical, tentative, and subjective NOS and she achieved to plan those aspects in an explicit reflective manner. Concerning NOS assessment, she planned asses NOS in her lesson plans starting from third lesson plan. She provided general assessment strategies such as asking NOS questions but she did not specify assessment strategies. Additionally, towards last lesson plans especially in fifth one she showed a consistency between the NOS aspects in objectives part the NOS aspects in the description of the activities part. That is, she stated a NOS aspect in objectives parts and also addressed same NOS aspect via instructional strategies in description of activities part. She did not use specific assessment strategies for each targeted aspects still she planned to assess NOS. She revealed that consistency specifically for empirical, tentative NOS and creative NOS for the whole lesson plans. That is, for those NOS aspects, she wrote objectives, addressed them in description of activities part through instructional prompts and also emphasized them in assessment part of the lesson plan. Following table summarized general overview of Lale's instructional planning regarding NOS objectives, NOS activities and NOS assessment:

Table 29. Summary of overall NOS instructional planning

Lesson plans	Grade level	Science content	NOS aspects	NOS teaching strategies	Explicit-Reflective NOS	NOS assessment	NOS objectives
1	6th	Atom models	Tentative NOS	Lecturing	Needs development	-	v-
2	7th	Solar system and space	Subjective NOS	Lecturing	Needs development	-	-
			Tentative NOS	Lecturing	Needs development	-	v-
			Creative NOS	Lecturing	Needs development	-	-
3	6th	Natural selection and evolution	Subjective NOS	HOS	Exemplary	v	v
			Creative NOS	HOS	Needs development	v	v-
			Tentative NOS	HOS	Exemplary	v	v
4	8th	Bacteria	Tentative NOS	HOS	Exemplary	v	v
			Subjective NOS	HOS	Exemplary	v	v
5	8th	Buoyancy force	Creative NOS	HOS	NA	v	v-
			Empirical NOS	HOS	Exemplary	v	v
			Creative NOS	HOS	Exemplary	v	v

v: indicated the existence of the task, -: indicated the lack of task, v- : indicated the incomplete of task

Following section will inform on participant's perceived source of development for NOS instructional planning.

4.2.3. Learning experiences contributing to the ability to integrate NOS into instructional plans

In general, Lale's instructional planning for teaching NOS has been evolved in an explicit reflective manner which included NOS objectives, specific activities for teaching NOS and specific assessment strategies for NOS. Researcher applied several strategies to improve participants' NOS instruction such as feedback to lesson plans, HOS based examples coupled with NOS explicitly followed by NOS discussions, and lesson plan presentations followed by NOS discussions. To understand the relative importance of these learning experiences, researcher conducted interview with the participants. Analysis of interview revealed that Lale perceived lesson planning activity which included creation and presentation of the lesson plan, as the main source contributing her ability to integrate NOS into instructional plans. Additionally, she also mentioned value of feedback given to the lesson plans:

R: As a researcher, I aimed to help you improve your NOS understanding and NOS instructional planning. For this reason, I applied several strategies such as giving feedback for lesson plans, providing HOS examples in class and asking you to prepare and present lesson plans, which was followed by class discussions. Which of these activities do you think influence your skills regarding NOS instructional planning?

L: Preparing lesson plan is the most contributing thing to me. While preparing it, we search for history of science. In that way, we learned both science in history and how to integrate them. We worked a lot for that. In fact, if you remember, our lesson plans were very poor at the beginning but later, we made certain improvement.

R: Hıhı.

L: For the first time, we prepared lesson plans seriously. Besides, there was the format of lesson plan. We integrate NOS to it [lesson plan] and in my opinion, it was useful in terms of learning HOS…I did not think the feedback you gave us were as a different activity [other than lesson planning] instead I thought that it is connected to it [lesson planning]

R: ok

L: When we got feedback about that topic, we saw our mistakes. Because, like I said, we had many shortcomings. Therefore, in terms of correcting the mistakes, I think that I can put feedback to second order [as a contributing activity to the development of NOS lesson planning]

4.3. CASE III

The third case of the study was named Lia. In the following, the results were presented related to (1) how his NOS understanding changed in the context of explicit reflective HOS based approach, (2) how progress trajectory in relation to integrating NOS into his lesson plans occurred as a result of feedback in the context of explicit reflective HOS based approach, and (3) what learning experiences contributed to his ability to integrate NOS into their instructional plans.

4.3.1. Change in NOS understanding

Following section will present participant's NOS views on tentative, empirical, inferential, creative, socio cultural NOS, theory and law, as well as subjective NOS. First, participant's view related to tentative NOS presented below.

Tentative NOS: Prior to NOS intervention, participant articulated the view that science is subject to change for all kind of scientific knowledge including scientific laws. Although he articulated the view of tentative NOS by giving example, his responses related to tentative NOS lacked of detailed explanation such that he did not explain how/ why scientific knowledge change. Instead he only stated change in scientific knowledge as a part of life. Therefore his view was categorized as adequate. However, Lia provided more extended explanation regarding tentative NOS at the outset of the study. He expressed that new evidence would lead in change in scientific knowledge. Moreover, he supported his assertion with an example. Therefore, his view on tentative NOS was categorized as informed view (see table30 below for sample quotas).

Table 30. Lia's sample statements related to tentative NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Adequate	It [scientific knowledge] changes because the development in science brings change which results in investigating different aspects. It is feature of life and knowledge. To illustrate this [tentative nature of scientific knowledge] Newton's law of motion which is x=v.t is valid in between 1700- 1900's but it is changed by Einstein's Relativity theory after 1930's
Post-VNOS-C	Informed	… It [science] may change in future. Kinetic molecular theory illustrates that. …new evidence, new data result in formation of new theories and laws, or change in existing theories or laws. For instance, Kinetic molecular theory changed over time. For instance, Boyle found the equation P1.V1=P2.V2, then Charles proposed different equation which was V1T1=V2T2, which both contributed to kinetic molecular theory

Participant's empirical NOS views were provided below.

Empirical NOS: At the beginning of the intervention, he displayed adequate understanding of empirical NOS. To be considered having adequate view, one needed to aware of that science is a testable procedure including observations and experiments but with lack of detailed explanation and examples. In Lia's case, he differentiated science from other disciplines by means of including measurement. Additionally, he also mentioned science involved experiments and observations. However, he did not explain the role of evidence. At the end of the intervention, his understanding shifted towards informed view of empirical NOS. That is, he recognized role of evidence to make claims and he also recognized evidence gathered through testable procedure. Additionally, he used the word "empirical" to differentiate science from other disciplines. (See table31 below for sample quotas).

Table 31. Lia's sample statements related to empirical NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Adequate	Science is different from other disciplines by its aspects of to measure and having valid result that affect life of all living organisms. Actually, it [science] is set of experiments and observations…
Post-VNOS-C	Informed	Scientific knowledge is testable and based on observable data. It [science] is empirical based that is, it is based on evidence…

Following section described participant's views on inferential NOS.

Inferential NOS: Ali showed adequate understanding for inferential NOS at the beginning of the intervention. That is, he implied for the recognition that scientists make inferences For instance; in his responses he indicated the understanding that scientists did not make direct observations of natural phenomena. Such that, in his reply to how scientists decided the existence of dinosaurs, he expressed that scientist examined the remaining of the dinosaurs. Over the science methods course, he shifted his understanding towards informed view of inferential NOS. That is, he could be able to state explicitly that scientists made inferences based on data at the end of the intervention. He expressed that scientists made inferences based on fossils (see table32 below for sample quotas).

Table 32. Lia's sample statements related to inferential NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Adequate	[To decide dinosaur's existence] scientists examine some remaining that belongs to animals. Also they make research on DNA.
Post-VNOS-C	Informed	[to decide dinosaur's existence]They gather some data like fossils and they infer that these fossils do not belong to any organism that known by scientists. Therefore they refer to a different animal now known as dinosaurs.

Subsequent section displayed participant's views on creative NOS.

Creative NOS: At the beginning of the intervention, he recognized role of scientists' creativity and imagination in development of scientific knowledge but mostly in particular stages of the scientific investigation. Therefore, his view was categorized as adequate. At the outset of the intervention, he was able to articulate role of scientists' imagination and creativity in all stages of the scientific investigation by providing example at the end of the intervention. Thus, his view was categorized as informed view (see table33below for sample quotas).

Table 33. Lia's sample statements related to Creative NOS revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Adequate	I think they [scientists] use their imagination and creativity in all steps [of scientific investigation] because in any steps they have unknown results. But mostly, it is the planning stage [of scientific investigation] that they [scientists] use imagination and creativity.
Post-VNOS-C	Informed	Through all steps of their investigation [scientific investigation], they [scientists] use their imaginations. For instance, Einstein used his creativity and imagination through all stages of thought experiments

Next, Lia's views on socio-cultural NOS were described.

Socio-Cultural NOS: At the beginning of the intervention, he revealed inadequate understanding of socio cultural NOS. He believed that science is value free of the society and culture. Yet, he achieved informed view at the end. That is, he recognized that science was influenced by the cultural values of society and supported his view with an example at the end of the intervention. In his response, he expressed explicitly that science could not be isolated from cultural values. He also supported his claim by giving example of Galileo case (see table34 below for sample quotas).

Table 34. Lia's sample statements related to socio cultural NOS revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	I want to believe the second choice [science is universal] but unfortunately science reflects social and cultural values…
Post-VNOS-C	Informed	Scientists are affected by social political issues as any person affected… we cannot isolate scientists from society they live in…They [scientists] obviously are influenced by society, environment and political conditions of the culture they live in. …For instance, Galileo, could not communicate the results of the his scientific investigation because of the scholastic pressure existed in Europe at that times.

Following section described participant's view on function of theories and laws.

Theory & Law: At the beginning of the intervention, Lia had the misconception that laws are more certain than theories. He stated that laws did not change because they were supported by lots of experiments. However, he shifted his view from inadequate to informed view at end of the intervention. That is, he appreciated role and function of theories and laws. He described laws as descriptive and theories as explanatory in nature. Additionally, he gave detailed explanation of theories and laws and also supported his explanation with an example (see table35 below for sample quotas)

Table 35. Lia's sample statements related to Theory &Law revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	...It [theory] is mainly based on predictions but may change because it is not law, that supported by uncountable experiments.
Post-VNOS-C	Informed	Theory is an explanation of relationship between events or organisms. Also it[theory] make explanation for behavior of organisms and process of events –cell theory, quantum theory….Law is a general expression related to relationship between events-Newtonian movements laws; Conversation of matter

Lastly, participant's views on subjective NOS were described below.

Subjective NOS: His response to pre VNOS-C regarding subjective NOS, could not be categorized. However his response to post VNOS-C revealed informed view for subjective NOS. At the outset, he recognized that scientists' interpretations would differ because of personal backgrounds, perceptions, pre conceptions and expectations by providing detailed explanation at the of the intervention. For instance, he described the dinosaur extinction controversy due to the different background of the scientists (see table36 below for sample quotas).

Table 36. Lia's sample statements related to Subjective NOS revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	NC	-
Post-VNOS-C	Informed	Scientists look at the same data but they interpret it differently, because, their prior knowledge, training, social structures and beliefs affect their work and investigations. For example in dinosaur case [existence of different theories on extinction of dinosaurs], scientists who deals with astronomy can think the extinction due to meteor hit while scientists who are interested in geology could think dinosaur extinction due to continental drift.

As a result, Lia held inadequate understanding on socio cultural NOS and theory &laws, and he showed adequate understanding on tentative, empirical, inferential, and creative NOS at the beginning of the intervention. He shifted his NOS views towards informed view for all aspects of NOS at the end of the study. Following section will inform on participant's progress on NOS instructional planning and the sources of her development for NOS instructional planning.

4.3.2. The progress trajectory in relation to integrating NOS into lesson plans

Following section will outline participant's progress for NOS instructional planning. First, general overview of his instructional planning, second, development of his instructional planning regarding NOS objectives, third, development of his instructional planning regarding NOS activities, fourth development of his instructional planning for NOS assessment and last general overview of her development for NOS instructional planning are presented. Next section started with general information about Lia's instructional planning.

4.3.2.1. Information about instructional planning in general

Participant turned in four lesson plans since he did not hand in his second lesson plan. He planned to teach the science topics such as *cell theory (6th grade)* in his first lesson plan, *properties of gases (6th grade*) in his third lesson plan*, gases pressure (6th grade)* for the fourth lesson plans, and *periodic table (8th grade)* for the last lesson plan. Additionally, he did not get any feedback from his first lesson plan, since he did not hand in it in time. However, he attended all class sessions from the beginning in which he saw his peers' lesson plan presentations (did micro teaching), NOS examples, provided by the instructor and discussions undertaken in class sessions. Similar to the previous ones, participant chosen all these science content for her lesson plans from Turkish science curriculum and it was his responsibility to choose and adapt any content from Turkish curricula to teach NOS. While adapting lesson plans, he was responsible for writing objectives part in which he stated his planned goals of the lesson, activities part referring to planned instructional strategies/tools to achieve his planned goals and evaluation part in which he stated planned strategies to assess his planned goals. Since all participants were required to plan teaching NOS in their lesson plans, all were expected to adapt and design lesson plans in which they address NOS explicitly. Subsequent section informed on participant's improvement in writing NOS objectives.

4.3.2.2. Development of lesson plan regarding NOS objectives

Objectives part of the lesson plans were more related with whether participants had the intention of teaching NOS explicitly. Inclusion of NOS objectives mostly indicated how they perceived teaching NOS e.g. they recognized NOS as an add-on, topic or as an important issue as the other science content to be taught/planned explicitly. Analysis of lesson plans revealed that Lia included NOS objectives in his all four lesson plans. In his **first lesson plan** in which he planned to teach "cell theory" his NOS objectives were more in an implicit manner. That is he did not include any objective directly related to science or how science works generally. Instead, the objectives were more content specific. For instance, he mentioned development of the cell theory in objectives part to address tentativeness. The objective he wrote was: "Explain development stages of cell theory". In a similar manner, he mentioned different explanations about cell theory in objectives part to emphasize subjective NOS inferred based on examination of description of activities part*: "Illustrate* different proposals of cell theory".

As mentioned previously, he did not turn in his **second lesson** plan but involved in class activities such as listening to peer's lesson plan presentations, and discussions on HOS examples provided by instructor regarding NOS. For the **third lesson plan**, he planned to teach gases as science content. He included two NOS objectives which were related to subjective NOS and creative NOS. Unlike with his previous lesson plan, he wrote NOS objectives on subjective and creative NOS directly related to science and how science works rather than being content specific. The objectives he wrote were: "Develop their knowledge of subjectivity of scientific knowledge" and "Understand the role of creativity in constructing scientific knowledge through history". However, in description of activities part he also mentioned that students would discuss theory and law, in addition to subjective and creative NOS. But he did not state any objective related to theories and law. The researcher encouraged him rethink about writing objectives on theory and law through giving feedback: "Why you did not include this (theory & Law) into your objectives."

In his fourth lesson plan, he planned to teach gases pressure as a science content. He included NOS objectives on tentative NOS and theory and law. Similar to his third lesson plan, his objectives were directly related to tentative nature of scientific knowledge, and role and function of theories and laws. The objectives he stated related to these NOS aspects were: "State examples to explain the tentativeness of scientific knowledge by using Kinetic Molecular Theory" and "Discriminate between law and theory". However, he also included empirical NOS in the description of activities part but he did not include objectives related to empirical NOS. Thus, the researcher warned him about including NOS objectives related to empirical NOS as well. In his **fifth lesson plan,** he planned to teach periodic table. Additionally he planned to include NOS objectives regarding subjectivity and creativity in science. The objectives were: "Will restate the role of creativity in science by giving examples from history of design of periodic table" and "Draw conclusion that subjectivity of scientific knowledge is exist by comparing past form of periodic table and modern form of periodic table". When we examined the all four lesson plans, it can be concluded he included NOS objectives in his all lesson plans. That is, it might be concluded that he had awareness about planning to teach NOS. Additionally, it was found that that his manner of writing NOS objectives were shifted from subject content specific to more "science"/ how "science works" related. That is, in his first lesson plan, his objective is related to development stages of cell theory and different explanations about cell theory .When we looked over directly to the objectives, it was hard to infer that these objectives targeting to teach science as tentative without examining the description of activities part of the lesson plan. However for the rest of the lesson plans, it was apparent that he planned to teach about nature of science, and he explicitly stated the aspects of science such as creativity, tentativeness of subjectivity of NOS in his objectives. Looking through the frequency of NOS objectives, subjective NOS was the most stated NOS objective among the others. The following table depicted the objectives that Lia stated in each lesson plan:

Table 37. NOS objectives in each lesson plan

# of lesson plans	Grade level	Science content	NOS aspects	NOS objective
1	6^{th}	Cell theory	Subjective NOS	Explain development stages of cell theory
			Tentative NOS	Illustrate different proposals of cell theory
2	NA	NA	NA	NA
3	6^{th}	Properties of Gases	Subjective NOS	Develop their knowledge of subjectivity of scientific knowledge
			Creative NOS	Understand the role of creativity in constructing scientific knowledge through history
4	6^{th}	Gases Pressure	Tentative NOS	State examples to explain the tentativeness of scientific knowledge by using Kinetic Molecular Theory
			Theory& Law	Discriminate between law and theory
5	8^{th}	Periodic table	Subjective NOS	Draw conclusion that subjectivity of scientific knowledge is exist by comparing past form of periodic table and modern form of periodic table.
			Creative NOS	Will restate the role of creativity in science by giving examples from history of design of periodic table

- : indicated the absence of the task, NA: not applicable

In addition to the lesson plans post interview and reflection papers were gathered at the end of the NOS intervention to use as data source to understand participant's NOS teaching perception and their development of NOS instructional planning. Interview included questions related to NOS objective writing as well as rationale for teaching NOS. Additionally, reflection paper was used to understand his perception of NOS teaching. Those data sources were used to support his manner of planned NOS teaching regarding to NOS objectives. Analysis of post interviews also revealed that he internalized teaching nature of science as planned explicitly, rather than as an add-on or side-content. Interview analysis indicated that he found inclusion of NOS objectives as "must" to make the teaching meaningful due to function of objectives in lesson plan. He found objectives of lessons something facilitating of teaching it, thus without having objectives regarding that content make teaching of it hard :

L: While preparing my last lesson plan, I figured out that it was meaningless and hard to teach something that you did not have in your objectives. Therefore, every issue that I taught [plan to teach] should include objectives.

The following section described the development of participant's explicit-reflective NOS instructional planning through the activities part of the lesson plan.

4.3.2.3. Development of lesson plans regarding NOS activities

That section of the findings part gave insights about in what ways and at what extent participant achieved to adopt explicit reflective approach to teach NOS in lesson plans/creating lesson plans. For instance **in the first lesson plan**, in which he planned to teach cell theory, he tended to have an implicit manner of teaching NOS. Although he had two content specific NOS objectives such as tentative NOS and subjective NOS, he did not emphasize these aspects in an explicit reflective manner. For instance, for tentative NOS, he gave an example from HOS which was Robert Hook's contributions to cell theory in this case. But he did not explain how Robert Hook's studies reflected how science/scientists work. He planned to give example without any further NOS discussion questions, or reflection opportunities for students. Therefore, his instructional plan for teaching tentative NOS categorized as "*poor*". Following sample from his lesson plan reflected how he planned to teach NOS:

"In 1839, Schwann made generalization for laws governing cells identical for plant and animal. He also supported Schlidens' idea that organisms composed of cell or cell products

(For animal). In 1852, Robert Remark generation schemes of Schkiden and Schwann. He said that binary fusion was the means of reproduction of new animal cells. (Tentativeness of knowledge). In 1879, Walther Flemming noted that chromosomes split longitudinally during mitosis. Also Wilhelm Roux said that each chromosome carried a different set of heritable elements and he support Flemmings' proposals with this idea. In 1904, Theodor Bovary confirmed this scheme. These discoveries are made by Mendel in 1866 also and these three scientists confirmed Mendel's hereditary laws…"

Similarly, for teaching subjective NOS which were categorized as "*poor"* as well, he did not connect the HOS example with NOS, or did not plan to include NOS questions either. The lesson plan revealed that he expected students to understand related NOS aspects from the example without any explicit connection to NOS as done for teaching tentative NOS.

Since he did not turn in his first lesson plan on time, he did not get any feedback. Thus any data regarding feedback was not mentioned in this part. Furthermore, he did not hand in his second lesson plan, thus current section is not mentioning analysis of second lesson plan. **In his third lesson plan,** his NOS teaching efforts was more explicit rather than implicit. He planned to teach subjective and creative NOS in the "gases science context" in which he covered the same NOS aspects in objectives part too. For instance, for teaching subjective NOS, he combined an inquiry based activity with HOS example to teach subjectivity. First, he talked about Torricelli experiment and then wanted students make a similar experiment investigating air pressure and compare their results with the ones Torricelli got. Following was the sample from his lesson plan illustrating his planned teaching of NOS:

"...Then we will talk about the first person who had measured the pressure of gases. After mentioning about Torricelli experiment (in 1643); we will try to made such an experiment with water in different groups and then compare our results with that Torricelli made and we will talk about the reasons of differences between two experiments…"

However he failed to add NOS questions to create a discussion environment on subjective NOS. Instead he tended to give direct definition of subjective NOS, but he revealed an incomplete understanding of subjectivity as indicated in the following sample of his lesson plan:

"…we will try to make such an experiment with water in different groups and then compare our results with that Torricelli made and we will talk about the reasons of differences between two experiments. Here the subjectivity of scientific knowledge will be stated and the role of creativity will be clearly understood. What conditions affect the results of experiment will be discussed…”

Therefore, the researcher gave him feedback about adding more specific NOS questions and making clear connection between the example and subjective NOS: “Could you make more clear connection between your example and subjectivity .Please write how different results of students and Torricelli’s related with subjectivity”. In same manner, in other part of description of activities part, he used another HOS example to address subjective NOS, However, his manner was more direct and lacked of explanation and discussion regarding subjective NOS:

“…After then the relationship between volume and pressure will be taught and the law that stated by Robert Boyle (1627-1691) will be given. It will be stated that pressure and volume are inversely proportional. That is; $P_1V_1=P_2V_2$ will be taught on different examples. Then we will have an activity by using balloon. We will fill the balloon with air and then get smaller its volume. The volume of the balloon will be estimated according to radius and when compressed the volume will change and the ratio between different pressures will be detected easily. Then Jacques Charles (1746-1823) stated the relationship between volume and temperature as; $V_1/P_1=V_2/P_{2.}$Here we could see the subjectivity of scientific knowledge; such that, although Boyle and Charles both examine same thing, gases, they reach different relations of gases by using different parameters…”

Thus, Lia was alerted on to be focused on how he would convey that example to teach subjective NOS. The researcher advised him to add some specific questions to start NOS discussions and lead students to think about subjective NOS. In sum, regarding his subjective NOS instructional planning, he included an objective on subjective NOS, and he also included some instructional prompts ensuring efforts to be reflective despite of the drawbacks. Therefore, his instructional plan regarding teaching subjective NOS was categorized as “*needs development*”. Regarding teaching creative NOS, although he included an objective on creative NOS, he did not provide any specific instructional prompts to emphasis it through description of activities part of the lesson plan. Instead, he assumed that creative NOS would be understood without any explicit emphasis of it. Due to the lack of reflective component, his lesson plan regarding teaching creativity was categorized as *“needs development”.* Thus, the researcher suggested him to have an explicit reflective manner for teaching creative NOS which included having specific questions directly lead students think about creative NOS, and providing students with reflection opportunities on creative NOS. The researcher advised him to have more specific instructional prompts to emphasize creative NOS: “You should indicate how these aspects [creativity] will be understood. You should indicate specifically .For instance you can say that I will ask that question.... to make discussion on creativity ....”, “…also you cam emphasis if Torricelli used his creativity while making experiment; etc…” Additionally, the researcher also gave some ideas on inclusion of some other aspects such as empirical NOS and theory & Law into *description of activities* part. Here, instructor alerted him on possible potential integration of some NOS aspects by advising to add some more NOS questions. Furthermore, the researcher also oriented him to analyze the examples and contexts in his plan regarding NOS integration opportunities. For instance, while he was talking about Torricelli experiment and proposed an activity on Torricelli experiment, Lia planned to integrate only subjective NOS. However, the researcher advised him also integrate empirical NOS here by starting a discussion on function of experiments and inferential nature of scientific knowledge: “It is so appropriate here to mention about what is an experiment; why we make experiments, do we have to make experiment always; what he infer from experiment and what is inference…”

In the **fourth lesson** plan, his planned teaching efforts for teaching NOS were more explicit and reflective compared to previous ones. He included various instructional strategies to teach NOS other than lecturing such as use of HOS examples and inquiry based activities. He planned to teach tentativeness, empirical basis, theory& law throughout the pressure of gases content. Analysis of lesson plan revealed that he took into consideration the feedback regarding theory & law and empirical basis from the previous lesson plan. He provided specific instructional strategies on theory and law and empirical NOS. That is, his efforts to teach theory & law and empirical NOS in a reflective manner were detected in his plan. Additionally, he included aspect of theory & law both in objectives and activities parts of lesson plan which ensures explicit component of his instructional planning. For instance, while he planned to teach theory & law, he well connected an example from HOS with the function and definition of theories and laws. He mentioned Gay Lussac’s law stating the relationship between pressure and temperature of gases and Kinetic energy theory. He asked questions about development of the kinetic energy theory, function of theories and relationship between theories and laws. His lesson plan regarding teaching theory & law was categorized *as “exemplary”.* Following sample from his lesson plan reflected his manner of planned teaching for theories and laws:

“Today we will study the Gay Lussac’s law. He also examined the gases and found that the pressure and temperature are directly proportional to each other. That is if you increase the temperature of a gases when the volume and mole of the gases are constant the pressure of the gases will increase. He concluded his study by this law; P1/T1=P2/T2. Now let’s think about the Kinetic Molecular Theory. Could you give examples from this theory through its history? Especially what do you think about the role of the theories? Why do scientists state the theories? Do all laws are based on a theory or not? Could you say that theories turn to laws or laws result in theories? As you studied until here, firstly gases laws are stated and then a theory, Kinetic Molecular Theory; developed. Do you think that laws may/must result in theories and theories may/must result in laws..."

Similarly, he used the process of development of kinetic molecular theory in history to address empirical NOS. Regarding empirical NOS, he provided HOS example then asked questions related to role of evidence:

"…..As you know the kinetic molecular theory has been developed after Boyle. After Boyle explained the relationship between pressure and volume, Charles explained the relationship between volume and temperature. Then Gay Lussac improved Kinetic Molecular Theory by explaining the relation of pressure and temperature. Considering this progresses; what do you think about the role of evidences in science and could you explain this progress with the point of view of NOS? Do you think that scientific knowledge needs evidences to be supported? (Students are expected to make inferences on the progress of Kinetic Molecular Theory and the role of evidences will be stated. That is in order to support a scientific idea scientists need to find evidences by making experiments or making observations etc…)"

Although he planned to address NOS through some instructional prompts, he did not include an objective on empirical NOS. In that sense his plan regarding teaching empirical NOS was lacking of explicit component. Therefore, his instructional planning regarding empirical NOS was categorized as *"needs development".*

Although he included NOS objective related to tentativeness, he did not provide any instructional prompt within the flow of lesson to address tentative NOS. Therefore his instructional plan regarding teaching tentative NOS was categorized as "*needs development*".

In his **fifth lesson plan**, he covered cell theory as science content. He covered creative and subjective NOS throughout the description of activities part of the lesson plan. He also provided objectives for these aspects. Concerning teaching creative NOS, he provided some information regarding creation of periodic table by two different scientists. Then, he included some questions on role of scientists' creativity in their work:

“…In 1869 the Russian chemist Dmitri Mendeleev and the German chemist J. Lothar Meyer, working independently, found that when the elements were arranged in order of atomic weight they could place them in horizontal rows (one under another), so that the elements in each vertical column had similar properties. This tabular arrangement of the elements in rows and columns, highlighting the regular repetition of properties of the elements is called a periodic table. Here I will ask; Whether or not these scientists (Dmitri Mendeleev J. Lothar Meyer) imagine the way to arrange the elements in order of periodic table?, Are the used their creativity to arrange elements in periodic table?, and what is the role of creativity in designing of periodic table?. I will force students to clarify the role of creativity in science by asking such questions. Also they are expected to state the meaning of creativity and its role in their own words…."

Regarding teaching subjective NOS, he used same HOS example on creation of periodic table. Similar with his instructional plan regarding teaching creative NOS, he provided some questions to emphasize subjective NOS too:

“….I will talk a bit about earlier periodic table that designed with respect to elements atomic weight. Here I will ask questions related to different periodic tables:

What are the differences between two tables?

Why the Mendeleev form a different periodic table although he also investigated the same data (elements)?

Could we infer that different scientists could draw different conclusions when investigating same data?

Could we infer that scientists are not objective when doing their study of science...?”

Here, analysis of lesson plan revealed that he showed intention of teaching creative and subjective NOS explicitly through providing objectives on creative and subjective NOS. Additionally, he also provided HOS example and used it to emphasize creative and subjective NOS through questions. Thus regarding being reflective for teaching creative and subjective NOS, his efforts to provide instructional prompts, such as HOS example, NOS questions were detected. Therefore, his lesson plan regarding teaching creative and subjective NOS was categorized as “*exemplary*”.

In general, Lia improved his instructional planning regarding description of activities part. In his first lesson plan; his manner of teaching NOS was implicit in his instructional plan. However, his teaching was shifted toward more explicit and reflective for the rest of three lesson plans. That is; he started to provide NOS objectives as well NOS specific instructional prompts to emphasize NOS explicitly and reflectively. He showed efforts to provide inquiry or HOS examples and connected these examples with NOS via questions. He specifically achieved explicit reflected NOS instructional planning regarding subjective, empirical NOS and function of theories and laws. He mostly planned to emphasize subjective NOS (three times) followed by empirical and tentative NOS. Following table illustrated the NOS aspects and teaching strategies used in each lesson plan:

Table 38. Summary of NOS aspects addressed in description of activities part of lesson plan

# of lesson plan	Grade level	Science content	NOS aspects	NOS teaching strategies	Explicit-Reflective
1	6th	Cell theory	Subjective NOS	HOS example	Poor
			Tentative NOS	HOS example	Poor
2	NA	NA	NA	NA	NA
3	6th	Properties of Gases	Creative NOS	Not applicable	Needs development
			Subjective NOS	HOS example/Inquiry based activity	Needs developmen
4	6th	Gases Pressure	Empirical NOS	HOS example	Needs development
			Tentative NOS	Not applicable	Needs development
			Theory& Law	HOS example	Exemplary
5	8th	Periodic table	Subjective NOS	HOS example	Exemplary
			Empirical NOS	HOS example	Exemplary

NA: not applicable

At the end of the NOS study, participant was interviewed and asked to write a reflection paper on his teaching perceptions of NOS. Interview also included questions on his perceived development of NOS instructional planning. In addition to lesson plans, analysis of post interview and reflection paper also supported his manner of teaching NOS. First, like his last two lesson plans, he stated that NOS should be taught in an explicit manner rather than implicit one through HOS. He stated NOS instruction should be integrated to science content as well.

L: it[NOS] should be integrated in the activities part of the lesson

R: as explicit or implicit?

L: - It should be explicit because it is very difficult to expect children in this level to understand NOS from implicit instruction.

R: how would be the explicit NOS instruction?

L: Explicitly, like I said, experiment assistants can use that method. It is possible for the teacher to teach it explicitly by using HOS. But nothing comes to my mind expect for these two examples.

He also stated he would teach NOS through HOS and inquiry revealed through reflection paper:

“I will use HOS to teach NOS aspects. If possible (in Turkey it is impossible) by doing experiments I will try to teach NOS”.

Following section presented participant’s NOS assessment strategies revealed through lesson plans.

4.3.2.4. Development of lesson plans regarding NOS assessment

That part of the *Results* section informed about Lia’s efforts to assess NOS aspects that he planned to teach. The kind of strategies that he used for each specific targeted NOS aspect was reported. The examination of lesson plans revealed that his manner to asses NOS was vague. In his first three lesson plans he did not evaluate NOS specifically. Actually in his first lesson plan he did not even plan to assess students’ content knowledge either. In his third lesson plan, he included an evaluation part but his assessment was lack of details. He only stated he would give homework to assess students’ knowledge regarding gases which he planned to teach in his third lesson plan. He was reminded on assessing targeted NOS aspects on lesson plan: “...What about assessing those [students] on targeted NOS aspects?”.

In his fourth lesson plan, he showed more vigorous manner to asses NOS. He planned assessment strategies specific to assess theory & law and tentative NOS which were stated in both objectives and description of activities parts of the lesson plan. Although, he planned to teach empirical NOS, theory &law and tentative NOS, he did not cover any specific assessment strategies to asses these aspects except for theory &law and tentative NOS. He adopted creation of comparison chart to assess theory &law understandings of students such that revealed in lesson plan: “Think about the laws and theory that you have learned and make a comparison chart for their differences”. For assessment of tentative NOS, he combined HOS with diagram creation on development of gases law and required students interpret their diagram regarding NOS. The sample of lesson plan illustrating his assessment manner was: “Design a historical diagram that show relationship between gases laws and interpret your diagram according to NOS and indicate the changes have been done in these laws. Could you refer that scientific knowledge may change, develop or not? Explain your reasons.” Although he showed explicit manner to asses NOS aspects in the fourth lesson plan, he tended to asses subjectivity and creativity aspects more implicitly in his last lesson plan: “Design a simple periodic table of metals. When you design your tables assume that you do not have any information about the atomic numbers of the elements. According to what characteristics of elements do you design your table? (Creativity subjectivity of students [creative and subjective NOS aspects] will be assessed)”.

Following table indicated brief description of each NOS assessment strategy used in the lesson plans:

Table 39. NOS assessment strategies used in each lesson plan

# of lesson plan	Science Content	NOS aspects	NOS assessment strategies
1	Cell theory	-	No NOS assessment
2	-	-	Not applicable
3	Properties of Gases	-	No NOS assessment
4	Gases Pressure	Theory &Law	Comparison Chart creation
		Tentativeness	Chart creation combined with HOS
5	Periodic table	Subjective NOS Creative NOS	Diagram creation

In general, he just planned to asses NOS aspects in the fourth lesson plan explicitly among the others. His way of NOS assessment was student-centered and targeting specific NOS aspects. Additionally, in the post interview which was conducted to understand participants' NOS teaching perceptions and perceived development of NOS instructional planning revealed that he also considered formative assessment for NOS evaluation. Although he did not consider the NOS related questions that he asked through the lesson plan in description of activities part as a formative assessment form, he stated formative NOS assessment in interview but he also stated lack of NOS assessment coverage through the course:

L: I think we did not emphasize assessment very much. I mean that the presentations in the class did not include it very much. As I understood that there was a difference 'n assessment: by using "questioning" method, assessment is used constantly.

Subsequent section presented an overview of the Lia's development regarding NOS instructional planning.

4.3.2.5. General overview for NOS instructional planning

In general, Lia developed his instructional planning for NOS regarding objectives, description of activities and evaluation parts of the lesson plan. Starting from the third lesson plan, he wrote objectives on NOS which he also addressed them in description of activities part of the lesson plan. Only in fourth lesson plan, he showed some vague manner of writing NOS objectives. That is, he did not provide objective on some NOS issues that he addresses through description of activities part.

Regarding description of activities part, her manner of teaching NOS in his plans shifted to more explicit reflective approach regarding NOS. Although his first instructional plan was implicit, he improved his planning for NOS for rest of the lesson plans. That is, he gave space for more NOS questions, and used HOS examples and inquiry based activities to address NOS explicitly and reflectively. He achieved explicit reflective NOS planning for subjective, empirical NOS and function of theories and law. Concerning with Lia's NOS views, he showed informed NOS views at the end of the study. However, he addressed empirical, tentative, creative, subjective NOS and function and role of theories and laws. However, as mentioned above, he only achieved explicit reflective instructional planning for subjective, empirical NOS and function of theories and law.

For NOS assessment, he started to consider assessing NOS towards the end of the lesson planning. That is, he did not evaluate any NOS issue in his first three lesson plans. However, he proposed some NOS assessment strategies such as chart creation in his fifth and fourth lesson plans. Regarding being consistent related to NOS, among objectives, description of activities and evaluation part of the lesson plans, he developed this consistency towards last two lesson plans. That is, in his fourth lesson plan, for theory & law, he provided an objective, achieved explicit reflective instructional planning and also proposed some assessment strategies specifically targeting to understanding of theory & law. He also showed that consistency in his last lesson plan for subjective and empirical NOS. That is he provided objectives, instructional prompts and assessment strategies related to these aspects. General overview of Lia's instructional planning regarding objectives, description of activities and evaluation parts of the lesson plans was summarized in the following table:

Table 40. Summary of overall NOS instructional planning

# of lesson plan	Grade level	Science content	NOS aspects	NOS teaching strategies	Explicit-Reflective	NOS objectives	NOS assessment
1	6th	Cell theory	Subjective NOS	HOS example	Poor	√-	-
			Tentative NOS	HOS example	Poor	√-	-
2		-	-	-	-	-	-
3	6th	Properties of Gases	Creative NOS	Not applicable	Needs development	✓	-
			Subjective NOS	HOS example/Inquiry based activity	Needs development	✓	-
4	6th	Gases Pressure	Empirical NOS	HOS example	Needs development	-	-
			Tentative NOS	Not applicable	Needs development	✓	✓
			Theory& Law	HOS example	Exemplary	✓	✓
5	8th	Periodic table	Subjective NOS	HOS example	Exemplary	✓	✓
			Empirical NOS	HOS example	Exemplary	✓	✓

√ :indicated the existence of the task, -:indicated the lack of task, √-:indicated the incomplete of task

Following section will inform on participant's perceived source of development for NOS instructional planning.

4.3.3. Learning experiences contributing to the ability to integrate NOS into instructional plans

In general Lia's lesson plans shifted from non NOS component lesson plans toward explicit reflective NOS covered lesson plans. Towards the last lesson plans specifically for fourth and last lesson plan his inclusion of NOS was more consistent and robust. That is he started include NOS objectives and cover same objectives in description of activities part explicitly and evaluated them as well. Researcher adopted several strategies to improve participants' NOS instructional planning such as feedback to lesson plans, HOS based examples coupled with NOS explicitly followed by NOS discussions, and lesson plan presentations followed by NOS discussions as well. To understand the relative importance of these learning experiences, researcher conducted interview with participants. Analysis of interview revealed that Lia perceived HOS based examples and feedback as main sources facilitating his NOS integration ability:

R: As a researcher, I aimed to help you improve your NOS understanding and NOS instructional planning. For this reason, I applied several strategies such as giving feedback for lesson plans, providing HOS examples in class and asking you to prepare and present lesson plans, which was followed by class discussions. Which of these activities do you think influence your skills regarding NOS instructional planning?

L: I think that the contribution of HOS cannot be ignored. It contributed so much. As a pre-service teacher, HOS had a serious role to success it [NOS instruction]…..We created lesson plans, but in the curricula, lesson plans are already pre-prepared. I think, presenting lesson plans did not contribute that much. But I got main contribution from HOS based examples and feedback.

He mentioned HOS based examples as a source of NOS examples that could be used while addressing NOS and he stated HOS examples as a tool to convey NOS in a more concrete way:

L: The example repertoire I had [regarding NOS] has been increased. Like I told before, in 1600s, a man said "atom is just like a cake and it can be split" In 900; another man said "it cannot be split". Maybe he told that a particular which is 1 million bigger than atom cannot be split. I had many examples now. For example, the time of the creation of a balloon, the process of the presentation of the shape of DNA. In that, I had many important examples to teach students that scientific knowledge can change socio cultural based etc. It contributes to my teaching skills [of NOS]. I think that HOS is the most catchy one [regarding NOS teaching] for pre-service science teachers. Because it [HOS] is concrete example, experienced life examples and it sounds like a story. Everybody likes stories.

Then the researcher asked about the role of feedback in his development of NOS instructional planning He stated the contribution feedback on his instructional planning as a mind opening experience regarding using HOS to address NOS:

R: Can you clarify more on how the feedback contributed to the your NOS instructional planning development

L: Feedbacks had the effect in this way: For example, while you are doing something, you assume that you understand the topic and you do it. Then, when you show it to the lecturer [researcher] s/he says “If you correct this, you will get closer to the right [regarding NOS integration].”Then you correct it. I barely included NOS in my first lesson plan. Then after the feedbacks, I noticed that I have lacking very much. When I was told that “you should integrate these things, where will you integrate what aspect of NOS”. In that way, I started to think on how I can integrate it [NOS aspects].After the integration, I get the feedbacks that “that point is missing, you have a mistake in that, and you may improve this”. These things have made contribution to me.

4.4. CASE IV

The fourth case of the study was Simge. In the following, the results were presented related to (1) how her NOS understanding changed in the context of explicit reflective HOS based approach, (2) how progress trajectory in relation to integrating NOS into her lesson plans occurred as a result of feedback in the context of explicit reflective HOS based approach, and (3) which learning experiences contributed to her ability to integrate NOS into their instructional plans.

4.4.1. Change in NOS understanding

Subsequent section informed on participant's views on tentative, empirical, inferential, creative, socio-cultural NOS, theory &law, as well as subjective NOS. Following section presented participant's tentative NOS views.

Tentative NOS: Prior to NOS intervention, Simge explicated that scientific knowledge change but if it is a theory. She stated that laws do not change. Therefore, her view was categorized as inadequate. However, she shifted her inadequate view towards informed view of tentative NOS at the outset. To be considered holding informed view of tentative NOS, one need to recognize that all scientific knowledge is subject to change with the new evidence, advancement in technology and reinterpretation of scientific knowledge. As in Simge's case, she expressed that scientific knowledge including laws and theories could change due to the new evidence (see table41 below for sample quotas).

Table 41. Simge's sample statements related to tentative NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	They [laws] do not change. Theory may change…
Post-VNOS-C	Informed	…when new traces [evidence] found or revised scientific knowledge can be developed, modified or changed completely. For instance, scientific laws and theories could be modified or changed completely because of improvements in technology and new improvements.

Subsequent section described participant's empirical NOS views.

Empirical NOS: Simge revealed inadequate view with regard to empirical NOS prior to NOS intervention. That is, she perceived experiments as to prove hypothesis rather than supporting scientists' claims. However, at the end of the intervention, she shifted her view towards informed view of empirical NOS. She could be differentiating science from other disciplines as science required evidence. Additionally, she also expressed that science involved experiments, observations and proposed models based on data (see table42 below for sample quotas).

Table 42. Simge's sample statements related to empirical NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	… In order to prove your hypothesis you [scientists] have to make experiments repeatedly see the results and confirm your hypothesis.
Post-VNOS-C	Informed	Science requires evidence to explain phenomena….Science come up with evidences. You [scientists] can do experiments, or observations, and propose models based on data you have….

Participant's inferential NOS views were presented below.

Inferential NOS: Simge showed adequate view of inferential NOS at the beginning of the NOS intervention. That is, she was aware of scientist made inferences, and science is not "what we see". For instance, in response to the VNOS-C-C question related to the appearance of the dinosaurs, her reply indicated that she was aware of that scientists did not directly observe the dinosaurs. She stated that scientists had fossils and combined bones but they were not certain about this combination. However, she did not emphasize making inferences directly. Therefore, her view was categorized as adequate view. At the end of the NOS intervention, she revealed an informed view of inferential NOS. She articulated that scientists make inferences based on data derived from observations and explanations. For instance, in her response to dinosaur extinction controversy, she explained that scientists infer different conclusions. Additionally, she also articulated that scientists' inferences were partially based on their imagination (see table43 below for sample quotas).

Table 43. Simge's sample statements related to inferential NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Adequate	… [to decide on existence of dinosaurs, scientists look at] Fossil records… They are not certain [regarding how dinosaurs look]. For example, they [scientists] combine the bones of dinosaurs. They [scientists], sometimes could not place a little bone [in the frame], it might be e.g. on upper nose or somewhere else in the body of dinosaur….
Post-VNOS-C	Informed	…when they look at the same data, they infer different conclusions… …..for instance, scientists make inferences on dinosaurs' digestion system, their appearance, habitat, their diet based on fossils and also with the help of their imagination and creativity.

Following section displayed participant's creative NOS views.

Creative NOS: At the beginning of the intervention, Simge showed inadequate understanding of creative NOS. She described science as a procedural activity which did not involve any imagination and creativity. Yet, she shifted her view from, inadequate to informed view of creative NOS at the outset. That is, she recognized role of scientists' creativity and imagination in all stages of scientific investigation. She also provided detailed explanation related to creative NOS (see table44 below for sample quotas).

Table 44. Simge's sample statements related to Creative NOS revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	No [regarding the role of scientists' imagination and creativity in scientific investigations]. They [scientists] are[only] collecting data, making experiments and calculate the results in order to confirm their hypothesis.
Post-VNOS-C	Informed	...they [scientists] use their creativity and imagination while constructing the dinosaur [model]... Scientists use their imagination and creativity at almost every stage of the scientific investigation. For instance, two different scientists could collect different kind of data and design different kind of experiments on same issue.

Participant's views on socio cultural NOS explained below.

Socio-Cultural NOS: Simge stated science as value and norm free from the culture in which it was practiced prior to NOS intervention. Therefore, her view was categorized as inadequate regarding socio-cultural NOS. However, she revealed informed view of socio cultural NOS at the end of the NOS intervention. She appreciated science as a discipline influenced by the norms and values of the culture. She supported her explanation by exampling scientists' religious beliefs' influence in research they conducted (see table 45 below for sample quotas).

Table 45. Simge's sample statements related to socio-cultural NOS revealed in pre- and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	I believe that science is universal and it does not reflect social and cultural values….
Post-VNOS-C	Informed	I believe now science reflects social and cultural values. For instance if a scientists believes in God, she/ he will try to connect the issues [scientific investigations] for existence of God (Einstein, Newton, Hawking)

Following section presented participant's views on function of theories and laws.

Theory & Law: At the beginning of the intervention, Simge revealed the common misconception related to the laws and theories that theories were rooted hypothesis and laws were the confirmed facts. However, she shifted her inadequate view towards informed view of theories and laws at the end of the NOS intervention. She recognized laws and theories as different kinds of scientific information. She described theories as explanatory and laws as descriptive in nature. Additionally, she also emphasized laws and theories equally valuable scientific knowledge (see table46 below for sample quotas).

Table 46. Simge's sample statements related to Theory &Law revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	Theory is rooted hypothesis. ….Law are confirmed facts acquired by doing experiments. They [laws] do not change.
Post-VNOS-C	Informed	Theory is an explanation about phenomena….Laws is statements which state relationships between something [phenomena] …..They[theories and laws] are different things they cannot be compared to each other

Subsequent section described participant's subjective NOS views.

Subjective NOS: Simge showed inadequate understanding with respect to subjective NOS prior to NOS intervention. That is, she could not explain the controversy of dinosaur extinction due to the fact that scientists' observations were filtered through the human perceptions and theoretical frameworks. Yet, she revealed informed understanding of subjective NOS at the end of the intervention. She showed the understanding that scientists' interpretations would vary because of personal backgrounds, perceptions, pre conceptions and expectations by providing detailed explanation at the end of the NOS intervention. For instance, she linked the dinosaur extinction controversy to the "subjective" nature of science. She explained that scientists brought out different conclusions because of their different education, pre-conceptions, and background (see table47 below for sample quotas).

Table 47. Simge's sample statements related to Subjective NOS revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	inadequate	There is more than one theory about extinction of dinosaurs and they are all logical and have some traces.
Post-VNOS-C	Informed	[regarding existence of different theories related to the dinosaur extinction] Because of the subjectivity aspect of nature of science….Every scientists has different prior knowledge, different kind of education, different background, thus, when they look at the same data, they infer different conclusions.

Participant showed inadequate understanding of NOS for all aspects, except she revealed adequate understanding for inferential NOS at the beginning of the intervention. She shifted her NOS views towards informed view for all aspects of NOS at the end of the study. Following section will inform on participant's progress on NOS instructional planning and the sources of her development for NOS instructional planning.

4.4.2. The progress trajectory in relation to integrating NOS into lesson plans

Current section outlined participant's development for NOS instructional planning. Participant's progress for NOS instructional planning was presented through following sub-sections: general information on participant's instructional planning, participant's development of instructional planning related to NOS objectives, participant's development of instructional planning related to NOS activities, participant's development of instructional planning related to NOS assessment and participant's overall progress related to NOS instructional planning. Subsequent section presented general information on participant's instructional planning.

4.4.2.1. Information about instructional planning in general

Participant handed in four lesson plans and she did not turn in first lesson plan. She planned to teach science content such as force and motion (6^{th} grade) in her second lesson plan, Structure of atom and periodic table (7^{th} grade) for her third lesson plan, Cell division and heredity (8^{th} grade) for her fourth lesson plan, and fertilization, growth and development (6^{th} grade) for her last lesson plan. Similar with the other participants, she chosen all the science content that she planned to teach from Turkish science curricula which was available online. It was her responsibility to choose any science content from curricula and adapt or modify it to address NOS explicitly. While creating lesson plans, she was in charge with the writing of objectives part of the lesson plan in which she stated the planned goals of her lesson, description of activities parts in which planned instructional strategies, tools were described to achieve the planned goals and lastly, evaluation part of the lesson plan, in which planned strategies were described to evaluate the planned goals. Since, all participants were required to teach NOS in their lesson plans, all were expected to adapt and design lesson plans in which they address NOS explicitly. The subsequent section presented Simge's improvement regarding including NOS objectives into her instructional planning.

4.4.2.2. Development of lesson plan regarding NOS objectives

Objectives part of the lesson plans were more related with whether participants had the intention of teaching NOS explicitly/consciously. Inclusion of NOS objectives mostly indicated how they perceived teaching NOS e.g. they recognized NOS as add-on, topic or as an important issue as the other science content to be taught/planned explicitly. Analysis of the lesson plans showed that Simge provided NOS objectives in all last three lesson plans but, she did not include any NOS objectives in her second lesson plan. In her **second lesson plan**, she did not provide any NOS objectives. Therefore, she was alerted to consider on function of objectives, and inclusion of NOS objectives: “Think about why you write objectives; do you think all these objectives cover what you intent to teach through the lesson; think about including objectives on NOS”.

For the third, fourth and fifth lesson plans she include NOS aspects in objectives parts. She mostly included objectives on tentative and empirical NOS. For instance, in her **third lesson plan,** which she planned to teach structure of atom and periodic table she provided two objectives on tentativeness which were as: “Recognize the tentativeness aspect of the nature of science with the help of the history of formation of periodic table” and “Discuss that theories may change over time with the help of the NOS”. Additionally she also provided one objective on empirical NOS and one objective on subjective one: “Recognize the empirical-based aspect of NOS with the help of the history of formation of periodic table” and “Recognize the subjectivity aspect of the NOS with the help of the history of formation of periodic table”. Additionally, she covered all these aspects in description of activities part as well.

In her **fourth lesson plan**, she covered cell division and heredity as science content. Similar with previous lesson plan she included two objectives on tentative NOS. These objectives were as followings: “Describe the tentativeness aspect of the nature of science with the help of the history of heredity” and “Discuss that theories may change over time with the help of the NOS”. She also included empirical NOS objective as well such as “Describe the empirical-based aspect of NOS with the help of the history of heredity”.

She provided NOS objectives related to subjective, empirical, creative and tentative NOS in her **fifth lesson plan**, in which she planned to teach fertilization, growth and development as science content. Regarding tentative NOS, she wrote: “Discuss that theories may change over time with the help of the NOS”. Regarding empirical, and subjective NOS, she planned to achieve students to be able to define these aspects: “Define the empirical-based aspect of

NOS with the help of the history of theories of reproduction" and "State the subjectivity aspect of the NOS". She also included creative NOS in objectives parts such as: "Discuss the creativity aspect of the NOS during the acquiring of the scientific knowledge".

In general, examination of lesson plans revealed her improvement regarding writing NOS objectives. It could be summarized that she adopted more robust manner of including NOS objectives throughout lesson planning. In her fist handed lesson plan, she did not include any NOS objectives, but she provided some specific instructional strategies to teach NOS in description of activities part. However, for the rest of the lesson plans she included NOS objectives. The following table showed the objectives that Simge stated in each lesson plan:

Table 48. NOS objectives in each lesson plan

# of lesson plans	Grade level	Science content	NOS aspects	NOS objective
1	-	-	-	-
2	6th	Force and Motion	Tentative NOS	-
			Empirical NOS	-
3	7th	Structure of atom and periodic table	Tentative NOS	Recognize the tentativeness aspect of the nature of science with the help of the history of formation of periodic table
				Discuss that theories may change over time with the help of the NOS
			Subjective NOS	Recognize the subjectivity aspect of the NOS with the help of the history of formation of periodic table
4	8th	Cell Division and Heredity	Empirical NOS	Describe the empirical-based aspect of NOS with the help of the history of heredity
			Tentative NOS	Describe the tentativeness aspect of the nature of science with the help of the history of heredity
				Discuss that theories may change over time with the help of the NOS
5	8th	Cell division and inheritance	Empirical NOS	Define the empirical-based aspect of NOS with the help of the history of theories of reproduction
			Subjective NOS	State the subjectivity aspect of the NOS
			Tentative NOS	Discuss that theories may change over time with the help of the NOS
			Creative NOS	Discuss the creativity aspect of the NOS during the acquiring of the scientific knowledge

- Indicated lack of the task

At the end of the NOS intervention, participants were interviewed and asked to write a reflection paper with regard to their NOS teaching perceptions. Specifically, interviews included questions related to perceived development of NOS instructional planning as well as NOS teaching perceptions. In addition to lesson plan analysis, analysis of post interviews and reflection paper also supported her manner about including NOS objectives. Her response to interview it was revealed that she did not have any difficulty in writing NOS objectives:

R: Considering the lesson plans that you are supposed to prepare for your teaching as a teacher in the future, do you think that NOS should be explicitly stated in the objectives part of the lesson plan?

S: I do not have problems with writing objectives. We do not have many examples [regarding NOS lesson plans]. I also searched internet but there are not many examples related to HOS lesson plans. We wrote the lesson plans with trial and error method…

Following section outlined participant development for addressing NOS in an explicit reflective manner.

4.4.2.3. Development of lesson plans regarding NOS activities

That section of the "findings" part informed about in what ways and at what extent participant achieved to adopt explicit reflective approach to teach NOS in lesson plans/creating lesson plans. For instance, in her **second lesson plan,** she planned to teach force and motion as science content and she planned to cover tentative and empirical NOS thorough the description of activities part of the lesson plan. She provided HOS based example which was related to different views of scientists related to force and motion through history. The sample of the lesson plan was provided below:

"…Mention Aristotle, Leonardo da Vinci, Galileo Galilee, Isaac Newton and Albert Einstein in historical order and explain thoughts and models about force and motion. Leonardo da Vinci made important contributions to static and applied mechanics. The real founder of the dynamic science is Galileo Galilei (1564) who was a professor in cities of Florence and Pisa. Not develop a theory about the mechanics of Galileo did not develop a theory about mechanics. His main contribution was developing empirical methods to test the hypothetical theories which were used by Newton later…"

However she did not provided any attempt to make clear connection to tentative or empirical NOS to students explicitly and reflectively. Her approach was implicit to teach these aspects. That is, she only provided HOS based example which was related to different scientists' views on force and motion throughout the history and expected students to understand these NOS aspects without any explicit reflective NOS emphasis. Additionally, she did not state any NOS objectives which also indicated lack of explicit reflective approach to teach those aspects. Thus, her plan regarding to tentative and empirical NOS was categorized as "*poor".*

In her **third lesson plan**, she improved her implicit way of NOS instructional planning towards more explicit reflective way. She covered structure of atom and periodic table as science content and integrated tentative, subjective, and empirical NOS. Unlike her previous lesson plan, she provided objectives on these NOS aspects. Similar with previous lesson plan, she provided HOS example related to history of periodic table. Sample of her lesson plan reflecting her manner of NOS teaching was presented below:

"….Give an introduction to lesson with the history of formation of periodic table: In 1789, Antoine Lavoisier published a list of 33 chemical elements. Although Lavoisier grouped the elements into gases, metals, non-metals, and earths, chemists spent the following century searching for a more precise classification scheme. In 1829, Johann Wolfgang Döbereiner observed that many of the elements could be grouped into triads (groups of three) based on their chemical properties…"

However, she could not able to connect HOS based example with NOS. That is, she did not provide any instructional prompt connecting HOS based example with targeted NOS aspects. Instead, she stated she would explain NOS issues via PowerPoint presentation. However, she did not provide any information on how she would emphasize NOS in her lesson plan:

"…I will explain this in PowerPoint presentation. At the end of the presentation I will explain the aspects of NOS explicitly which are namely tentativeness, subjectivity and empirical-based…."

Although she lacked of providing NOS questions, creating NOS discussion, or any explicit NOS reference, inclusion of these NOS aspects in objectives part of lesson plan indicated her effort/intention to teach NOS explicitly. That is, her lesson plan needed more components to achieve reflective, but inclusion of NOS objective remedied to be explicit. Thus, her lesson plan was categorized as "*needs development*". Additionally, because of unclear manner regarding how she would integrate NOS, she got alerted on flow of lesson plan regarding NOS and integration of these aspects as the following by the researcher: “You should point out at which part you will mention these aspects how you will integrate these aspects through which questions…”

In her **fourth lesson plan,** she covered tentative and empirical NOS throughout description of activities part in the context of cell division and heredity. Similar with the third lesson plan she provided HOS example which was related to history of heredity. She provided students with different theories proposed through the history

In her **fourth lesson plan,** she covered tentative and empirical NOS throughout description of activities part in the context of cell division and heredity. Similar with the third lesson plan she provided HOS example which was related to history of heredity. She provided students with different theories proposed through the history in her lesson plan:

“…The ancients had a variety of ideas about heredity: Theophrastus proposed that male flowers caused female flowers to ripen. Hippocrates speculated that "seeds" were produced by various body parts and transmitted to offspring at the time of conception. Aristotle thought that male and female semen mixed at conception. Aeschylus, in 458 BC, proposed the male as the parent, with the female as a "nurse for the young life sown within her. Various hereditary mechanisms were envisaged without being properly tested or quantified. These included blending inheritance and the inheritance of acquired traits. Nevertheless, people were able to develop domestic breeds of animals as well as crops through artificial selection. The inheritance of acquired traits also formed a part of early Lamarckian ideas on evolution…”

Unlike the third lesson plan, she was able to connect example with tentative and empirical NOS. She prepared some NOS questions to emphasize NOS throughout a HOS based example. For instance, after she provided HOS examples, she planned to ask a question to initiate NOS discussion such as: “What are the NOS aspects in this history of heredity?. She also specifically added NOS questions regarding tentative and empirical NOS which were revealed in the following sample part of fourth lesson plan:

“After explaining the history, I will ask questions to the students about the aspects of the NOS in this part. These are the questions: What are the NOS aspects in this history of heredity?, Can we say that scientific knowledge may change over time by looking the development of heredity theories?, Can we say that there is a single scientific method to reach the scientific knowledge?. At the beginning, scientist speculated about the heredity. Can we infer that scientific knowledge can be constructed without doing experiment?, What are the experiments that scientist did in order to try to explain the heredity? And what are the NOS aspects in this process? And Why scientific knowledge changed or improved..."

In sum, she was able to addressed targeted NOS aspect in objectives part and also be able to connect HOS example with NOS questions. Therefore, she achieved to explicit reflective NOS instructional planning in her plan and categorized as *exemplary* for both tentative NOS and empirical NOS instructional planning.

Her **last lesson plan** was on fertilization, growth and development which were in the sixth grade curriculum. She also planned to teach empirical, creative, tentative and subjective NOS which were stated in objectives part as well. Like her previous lesson plans, she provided students a reading script on history of generation. The sample from her lesson plan was provided below:

"…In 1745 - 1748, John Needham, a Scottish clergyman and naturalist showed that microorganisms flourished in various soups that had been exposed to the air. He claimed that there was a "life force" present in the molecules of all inorganic matter, including air and the oxygen in it that could cause spontaneous generation to occur, thus accounting for the presence of bacteria in his soups. He even briefly boiled some of his soup and poured it into "clean" flasks with cork lids, and microorganisms still grew there. A few years later (1765 - 1767), Lazzaro Spallanzani, an Italian abbot and biologist, tried several variations on Needham's soup experiments. First, he boiled soup for one hour, and then sealed the glass flasks that contained it by melting the mouths of the flasks shut…"

Then the reading script was continued with giving definitions of targeted NOS aspects in plan and providing some NOS questions. She addressed subjective, creative and empirical NOS by giving their definitions directly instead of connecting that HOS script on generation with NOS. The part of lesson plan reflected the NOS emphasis was provided below:

"…From the history, we can say that every scientist has different prior knowledge and therefore they construct different ways to reach the scientific knowledge. This is the subjectivity aspect of the NOS. and we can also say that there is no single scientific method to conduct the knowledge. During this, scientist offer different models or theories about the same topic. While doing these, they imagine and use their creativity. This is called creativity aspect of the NOS. Thirdly, science requires evidences constructing the scientific knowledge different from other disciplines. This is called the empirical aspect of the NOS…"

Then, later in her lesson plan, she provided some questions on how the HOS example reflected NOS. The questions were as followings:

"Let's back to the presentation, I want to ask some question about the NOS aspect: What are the NOS aspects in these theories of reproduction?

Can we say that scientific knowledge may change over time by looking the reproduction theories? What is the name of this aspect in NOS? (Yes. Tentativeness)

Can we say that there is a single scientific method to reach the scientific knowledge? (For this question, I will wait for students to think that every scientist designs their own experiment and they use their imagination and creativity for these observations, experiments etc.)

At the beginning, scientists speculated the about the theories from their inferences. Can we say that scientific knowledge can be constructed without doing experiment? (Yes. There is no single scientific method for getting the knowledge)

Although Simge provided some NOS questions to create reflection opportunities, the questions she wrote were mostly "yes-no" questions. Additionally, she provided definitions of the each aspect directly before giving the questions in her lesson plan. Therefore, she arranged weak reflection opportunities for students regarding nature of science. In that sense, her manner of teaching NOS, was more lecturing rather than providing reflective opportunities for students because, she lectured all these aspects directly initially. Although she wrote some questions the questions were more likely the questions for assessment at the end. Therefore, her planning was categorized as *needs development* regarding NOS planning with respect to aspects mentioned above.

Overall examination of lesson plans revealed that she improved her instructional planning towards more explicit reflective way of teaching NOS. She mostly used HOS examples in her plans to address NOS. Although, she was lack of in providing instructional prompts to emphasis NOS, at least she achieved, to shift her lesson plans being implicit to somehow explicit reflective /needs development regarding NOS instructional planning. Specifically, she succeeded explicit reflective NOS instructional planning regarding tentative and empirical NOS in her fourth lesson plan.

She was interviewed and asked to write a reflection paper on her NOS teaching perception at the end of the NOS intervention. Analysis of responses to interviews and reflection paper also supported her manner of NOS teaching approach in her lesson plans. For instance, in post interview, she stated that she would teach NOS as an embedded to content by using HOS:

R: How would you teach NOS, in what way?

S: I would integrate NOS into the science content

R: how would you integrate it?

S : For instance, while teaching planets I would address tentativeness by saying pluton is not a planet any more, the definition of planet was redefined or [another example] I would mention Archimedes as he influenced his religious view while stating earth as the center of universe. But by the help of observations, experiments scientific knowledge changed…I would mention tentative NOS through HOS.

In her reflection paper, she stated she would emphasis more meaning of these aspects instead of presenting NOS as set of postulates:

“I will not give the NOS definition; I will give some clues for elementary students. For instance, I will say “scientific knowledge can change over time” instead of “tentativeness means… This is one aspect of the NOS”.

Following table indicated each NOS aspect she planned to teach in the *activities part,* and the instructional strategies she planned to use to teach NOS:

Table 49. Summary of NOS aspects addressed in description of activities part of lesson plan

# of lesson plan	Grade level	Science content	NOS aspects	NOS teaching strategies	Explicit-Reflective
1	NA	NA	NA	NA	NA
2	6th	Force and motion	Tentative NOS	HOS example	Poor
			Empirical NOS	HOS example	Poor
3	7th	Structure of atom and periodic table	Subjective NOS	HOS example(HOS reading script)	Needs development
			Tentative NOS	HOS example(HOS reading script)	Needs development
			Empirical NOS	HOS example (HOS reading script)	Needs development
4	8th	Cell division and heredity	Tentative NOS	HOS example	Exemplary
			Empirical NOS	HOS example	Exemplary
5	8th	Fertilization, Growth, Development	Empirical NOS	Lecturing	Needs development
			Creative NOS	Lecturing	Needs development
			Subjective NOS	Lecturing	Needs development
			Tentative NOS	Lecturing	Needs development

NA: not applicable

Next, participant's development in NOS assessment revealed through lesson plan analysis was presented.

4.4.2.4. Development of lesson plans regarding NOS assessment

That part of the Results section gave insights about Simge's efforts to assess NOS aspects that she planned to teach. The kind of strategies that she used for each specific targeted NOS aspect was reported. Examination of Simge's lesson plans revealed that she mostly did not evaluate students' NOS understanding in her lesson plans. For instance, in her **second lesson plan**, she stated that she gave homework in evaluation part of lesson plan, but she did not give any details regarding homework. Moreover, she did not specify any strategy for assessing NOS aspects that planned in lesson plan. Thus she got alerted thinking on assessing the NOS aspects that she planned to teach in her lesson plan: "So how you plan to assess students' understanding of NOS on various [targeted] NOS aspects".

For **third, fourth and fifth lesson plans** she did not specify any assessment strategy regarding NOS. Although she included evaluation parts for these lesson plans except the fourth lesson plan, she did not specify any assessment strategy regarding NOS issues. Instead, she stated she would evaluate students through a formative assessment. For instance in her **third lesson plan,** evaluation was as the followings:

"Evaluation: Performance during the lesson [based on students'] attention to the topic, participation to activity…"

Similarly, in her **fifth lesson plan**, she stated she would assess students through the questions she asked during the class, but she did not provide any evaluation part for **fourth lesson plan**:

"I will evaluate the student while asking the questions"

Correspondingly, post interview was conducted to understand participant's perception of NOS assessment as well. Responses to interview also supported her repeated manner of assessment. She stated that she would assess students' performance during the class. However, she did not state any specific task to assess students' NOS understanding:

R: Considering the lesson plans that you are supposed to prepare for your teaching as a teacher in the future, do you think that NOS should be explicitly stated in the objectives part of the lesson plan?

SİNEM- You can evaluate students NOS understanding by looking for their performance, their involvement, their answers to the questions throughout the academic term. Maybe we do not have time for quizzes in every lesson. If you go to the public school, there may be other work to do. Maybe you can do your teaching in 25 minutes of 40 minutes. In the rest of the time, you try to gather the attention of the class…At the end of the lesson; you can make a written exam or oral exam to evaluate how much they know about NOS.

Subsequent section presented an overview of the participant's development regarding NOS instructional planning.

4.4.2.5. General overview for NOS instructional planning

In general, analysis of lesson plans indicated Simge's development of NOS instructional planning regarding objectives, description of activities and evaluation parts. Regarding NOS objective, she did not include any NOS objectives in her first lesson plan, but she provided NOS objectives for the rest of the lesson plans. Regarding description of activities part, she shifted her implicit way of teaching NOS into more explicit and reflective manner. However, she lacked of reflective component in her instructional plans. That is, she mostly did not provide efficient instructional prompts regarding NOS to enhance students' understanding of NOS. Her plans were mostly lacking of an NOS questions to initiate NOS discussions and connections between HOS examples and NOS. She only achieved explicit reflective NOS instructional planning in her fourth lesson plan for tentative and empirical NOS. Relating to her NOS views, she achieved informed understanding for all NOS aspects, but only addressed tentative, empirical, subjective and creative NOS in her plans but achieved explicit reflective NOS instructional planning for only tentative and empirical NOS. Regarding NOS assessment, she did not consider assessment of NOS in her lesson plans. Moreover, starting from third lesson plan, she stated NOS in objectives part, and she also gave place in the description of activities part of lesson plan. However, she failed to show that that consistency for evaluation part. Following table summarized Simge's general overview of instructional planning regarding objectives, description of activities part and evaluation parts of lesson plans:

Table 50. Summary of overall NOS instructional planning

# of lesson plan	Grade level	Science content	NOS aspects	NOS teaching strategies	Explicit-Reflective	NOS objectives	NOS evaluation
1	NA	NA	NA	NA	NA	NA	NA
2	6th	Force and motion	Tentative NOS	HOS example	Poor	-	-
			Empirical NOS	HOS example	Poor	-	-
3	7th	Structure of atom and periodic table	Subjective NOS	HOS example	Needs development	✓	-
			Tentative NOS	HOS example	Needs development	✓	-
			Empirical NOS	HOS example	Needs development	✓	-
4	8th	Cell division and heredity	Tentative NOS	HOS example	Exemplary	✓	-
			Empirical NOS	HOS example	Exemplary	✓	-
5	8th	Fertilization, Growth, Development	Empirical NOS	Lecturing	Needs development	✓	-
			Creative NOS	Lecturing	Needs development	✓	-
			Subjective NOS	Lecturing	Needs development	✓	-
			Tentative NOS	Lecturing	Needs development	✓	-

√ : existence of the task, NA: not applicable, -. Absence of the task

Following section will inform on participant's perceived source of development for NOS instructional planning.

4.4.3. Learning experiences contributing to the ability to integrate NOS into instructional plans

In general, Simge's instructional planning for teaching NOS has been evolved in an explicit reflective manner which included NOS objectives, specific activities for teaching NOS. Researcher applied several strategies to improve participants' NOS instructional such as feedback to lesson plans, HOS based examples coupled with NOS explicitly followed by NOS discussions, and lesson plan presentations followed by NOS discussions as well. To understand the relative importance of these learning experiences, researcher conducted interview with the participants. Analysis of interview revealed that Simge perceived follow up discussions after peer presentations of lesson plans as the main source contributing to her ability to integrate NOS into instructional plans:

R: As a researcher, I aimed to help you improve your NOS understanding and NOS instructional planning. For this reason, I applied several strategies such as giving feedback for lesson plans, providing HOS examples in class and asking you to prepare and present lesson plans, which was followed by class discussions. Which of these activities do you think influence your skills regarding NOS instructional planning?

S: The discussions in the class were very useful.

R: How would it contribute to?

S: We learned much better. There was a face to face communication. I think that discussing them actively were very useful… It [discussions] contributes to my viewpoint, I consider different perspectives… We prepared the new lesson plans after we took feedbacks from you but we could not correct it because we did not have a strict template. We prepared different lesson plan with different content for the coming week and you gave feedback to it as well. We did not understand what to do. These were the things [lesson plan preparation and feedback] that contributed least. We did not provide the communication.

4.5. CASE V

The fifth case of the study was Ebru. In the following, the results were presented related to (1) how her NOS understanding changed in the context of explicit reflective HOS based approach, (2) how progress trajectory in relation to integrating NOS into her lesson plans occurred as a result of feedback in the context of explicit reflective HOS based approach, and (3) which learning experiences contributed to her ability to integrate NOS into their instructional plans.

4.5.1. Change in NOS understanding

Participants' NOS views on tentative NOS, empirical NOS, inferential NOS, creative NOS, socio-cultural NOS, theory & law and subjective NOS, were presented in current section. First, participant's views related to tentative NOS presented below.

Tentative NOS: Ebru showed inadequate understanding of tentative NOS prior to the NOS intervention. Her responses in pre-VNOS-C revealed that **s**he had some doubts regarding tentative NOS by implying scientific knowledge as definite. She revealed her incomplete understanding of tentative NOS by stating laws as certain. At the end of the intervention, she recognized science as tentative due to technological enhancements and new data, and she also exemplified it. For example, she stated that scientific knowledge including theories and laws will change due to the new evidence. She also exemplified her claim with the case of atom models, evolution theory and Newton laws (see table51 below for sample quotas)

Table 51. Ebru's sample statements related to tentative NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	Theories and hypothesis could change…Laws do not change…….
Post-VNOS-C	Informed	It [scientific knowledge] may change with the improving technology and finding new fossils records [new evidence]. Scientific knowledge may change in time. For example, in evolution theory Lamarck theory has not been accepted anymore because of the Darwin's theory. …. there is no %100 certainty in science… …since theories and laws are scientific knowledge, they will change too….For instance, atom models, they changed and developed in time…Newton law changed…

Participant's empirical NOS views were provided below.

Empirical NOS: Prior to NOS intervention, Ebru revealed inadequate view of empirical NOS. Although she stated that science was different from other disciplines by means of experiments, she perceived experiments to prove and understand scientific facts. However, she shifted her understanding towards adequate view of empirical NOS at the outset of the intervention. The indication of adequate view was referring experiments and observation to differentiate science from other disciplines without an explicit emphasize on evidence or empirical basis. For instance, Ebru stated that science included observations and experiments as distinct from other disciplines. She also indicated that scientists supported their claims throughout the experiments and observations. However, she did not mention evidence or empirical basis explicitly. Thus, her view was categorized as adequate view. (See table52 below for sample quotas.

Table 52. Ebru's sample statements related to empirical NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	…It is the experiment part that makes science different form other disciplines. For instance, to understand and prove buoyancy we need experiments whereas for sociology of philosophy there no mathematical experiments…
Post-VNOS-C	Adequate	Science includes observation, experimentation data collection interpretation of these data etc. On the other hand other subjects [philosophy, religion etc.] do not include such kind of aspects of NOS. Scientists could support their claims with the help of experiments, observations…

Following section described participant's views on inferential NOS

Inferential NOS: Prior to the intervention, Ebru revealed inadequate understanding of inferential NOS. She held the belief that scientists observed the natural phenomena directly and got conclusions. She did not show the understanding that all natural phenomena was not accessible to the senses and scientist also made inferences. For example, in her responses she implied that experiments yielded all the true conclusions denying the idea that scientists actually make inferences based on data gathered through the experiments. Moreover, in her responses related to the appearance of the dinosaurs, she stated that scientists might have seen drawings of the dinosaurs left from the ancient times to decide the look of dinosaurs. Therefore, her view was categorized as inadequate for inferential NOS understanding. However, she shifted her understanding towards informed view for inferential NOS at the end of the intervention. That is, she recognized that scientists made inferences based on experiments and observations. In her responses, she clearly explicated that scientists made inferences. Additionally, regarding the response on appearance of dinosaurs she also expressed that scientists created the dinosaur model based on the evidence they gathered (see table53 below for sample quotas)

Table 53. Ebru's sample statements related to inferential NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	….sometimes mathematical conclusions can be required to prove a reality. For example nobody can say that water boils at 100C without experiment. There should be an experiment to say this… [To decide existence of dinosaurs] scientists are investigating fossils and maybe in ancient times, people drew dinosaur's pictures, so they [scientists] examine fossils and drawings.
Post-VNOS-C	Informed	…. [to decide existence of dinosaurs] They [scientists] found some fossil records such as some bones they think that dinosaurs existed…They found only two bones which belonged to dinosaurs. By using these two bones, scientists created dinosaur model…. …..It [science] includes scientists' observations, inference, experimentation etc…

Subsequent section displayed participant's views on creative NOS.

Creative NOS: She had inadequate view of creative NOS at the beginning of intervention. That is, she did not appreciate role of scientists' imagination and creativity in development of scientific knowledge. She expressed science as an activity only depended on experiments and scientists' imagination would impair their objectivity. Yet, she shifted her inadequate view towards informed view of creative NOS. That is, she appreciated role of imagination and creativity in all stages of scientific investigation. For instance, she recognized that constructing dinosaur model included mostly scientists' creativity (see table54 below for sample quotas)

Table 54. Ebru's sample statements related to Creative NOS revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	…there should not be any imagination [in science] which can only depend on experiment in science. … Scientists do not use their imagination and creativity in science so that, they become objective.
Post-VNOS-C	Informed	..In all parts [of scientific investigation] planning investigation observations interpretation etc. they use their imagination and creativity….For instance, designing a dinosaur model is all related to scientists' creativity

Next, participant’s views on socio cultural NOS were presented.

Socio Cultural NOS: At the beginning of the intervention, Ebru revealed inadequate understanding of socio cultural NOS. She believed that science is as value free discipline in which it was practiced within its culture. In her responses she described science as universal holding the fact that science was only based on experiments. However, she achieved informed view of socio cultural NOS at the end of the intervention. She recognized that science was influenced by the culture and values of society. She supported her view with an example as well (see table55 below for sample quotas). For instance, she clearly stated that science reflected the social values of culture in which it was practiced. Moreover, she supported her claim with an example representing the case in Turkey related to evolution controversy preventing some Turkish scientists to study this issue.

Table 55. Ebru’s sample statements related to socio-cultural NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	Science is universal. Because it depends on only experiment, investigations and statistics….
Post-VNOS-C	Informed	Science reflects socio cultural values. Because scientists are human beings. It is impossible that, they are not affected their culture and society which they live in. Even their expertise fields are determined by their culture. For example, in Turkey, working about evolution is not very easy and the number of scientists who work about evolution is very low. This is due to the religion in Turkey

Following section described participant’s view on function of theories and laws.

Theory & Law: Prior to the intervention, Ebru held the misconception that there was a hierarchical order between theories and laws. She expressed that law was the last product of the scientific investigation. In other words, she believed that theories became law when they were proved. Yet, she shifted her view from inadequate to informed view at end of the intervention. That is, she appreciated role and function of theories and laws. She explained theories as explanatory and laws as descriptive. She also supported her explanation with an example of atom theory and Newton's Law representing the difference between theory and law (see table56 below for sample quotas)

Table 56. Ebru's sample statements related to Theory &Law revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	Theory is the real thing which is proved by experiments and supported by scientists. ….Law is the last stage after theory. It is the last product of scientific investigation and they [laws] do not change. Theories become law when they are proved and accepted by all [scientists]
Post-VNOS-C	Informed	Theory is the explanation of the natural phenomena. ….Law is the relationship between the natural phenomena. …. For example[regarding difference between theory and law] atomic theory explains the structure of atom, second law of Newton shows the relationship between mass and acceleration

Lastly, participant's views on subjective NOS were described below.

Subjective NOS: Ebru could not recognize role of scientist's' subjectivity while conducting scientific investigations and making scientific propositions at the beginning of the intervention. For instance, in response to the VNOS-C-C question related to the dinosaur extinction controversy, she indicated that the reason behind the dinosaur extinction controversy related to the equipment and tools used by scientists. That is, she ignored the role of scientists 'perceptions and theoretical frameworks. However, she recognized that scientists' interpretations would vary because of personal backgrounds, perceptions, pre conceptions and expectations by providing detailed explanation at the end of the intervention. She clearly explained that variations in explanations on a scientific issue reflected the subjective nature of science. Thus, her view was categorized as informed view (see table57 below for sample quotas)

Table 57. Ebru's sample statements related to Subjective NOS revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	…. [regarding different theories on extinction of dinosaurs] I think there may not be a lot of reason of this extinction] according to scientists. So every scientist has its own idea. Moreover conditions and materials may not be enough to find real [dinosaurs'] extinction reason…
Post-VNOS-C	Informed	Each scientist has his/her own prior knowledge, training, creativity, experience and expectations. Due to these differences their conclusions are different from each other's although they all have same information. This is the subjectivity aspect of NOS.

To sum up, participant showed inadequate understanding of NOS for all aspects prior to the study. She shifted her NOS views towards informed view for all NOS aspects, at the end of the study. Following section will inform on participant's progress on NOS instructional planning, and the sources of her development for NOS instructional planning.

4.5.2. The progress trajectory in relation to integrating NOS into lesson plans

Current section outlined participant's NOS instructional planning in terms of general overview of her instructional planning, development of her instructional planning related to NOS objectives, development of her instructional planning related to NOS activities, development of her NOS instructional planning related to NOS assessment and lastly, general overview of her NOS instructional planning. Next section provided general information related to Ebru's instructional planning.

4.5.2.1. Information about instructional planning in general

Participant handed in five lesson plans. She planned to teach science content such as atom models (grade7) in her first lesson plan, Formation of universe (grade 8) in her second lesson plan, Heritage (grade 8) in her third lesson plan, electricity (grade 7) in fourth lesson plan, and electricity (grade 8) for the last lesson plan. Similar with the other participants, she chose any science content that she planned to teach from Turkish science curricula which was available online. While creating lesson plans, she was in charge with the writing of objectives part of the lesson plan in which he stated the planned goals of her lesson, description of activities parts in which planned instructional strategies, tools were described to achieve the planned goals and lastly, evaluation part of the lesson plan, in which planned strategies were described to evaluate the planned goals. Since all participants were required to teach NOS in their lesson plans, all were expected to adapt and design lesson plans in which they address NOS explicitly. Subsequent section presented participants development regarding NOS objective writing.

4.5.2.2. Development of lesson plan regarding NOS objectives

Objectives part of the lesson plans were more related with whether participants had the intention of teaching NOS explicitly/consciously. Inclusion of NOS objectives mostly indicated how they perceived teaching NOS e.g. they recognized NOS as an add-on, topic or as an important issue as the other science content to be taught/planned explicitly. Analysis of the lesson plans showed that Ebru's manner towards including NOS objectives was shifted from no inclusion of NOS objectives towards inclusion of NOS objectives which were both described through description of activities part of the lesson plan and evaluated in evaluation part of the lesson plan as well. **In her first lesson plan she did not address any NOS objective.** Although she included subjective, empirical, tentative and creative NOS in description part of the lesson plan, she did not include any objectives related to these aspects. Since she handed it late, she did not get any feedback. **In her second lesson plan,** in which she planned to teach "formation of universe" she did not included any NOS objective. However she claimed to include instructional activities/tools to address empirical, creative, tentative and subjective NOS in description of activities part of the lesson plan. A similar case is observed in her **third lesson plan,** in which she planned to teach heritage she kept the same manner, and did not include any NOS objective, although she planned to include instructional strategies covering empirical and tentative NOS in description of activities part. For both lesson plans (lesson plans 2, 3) the researcher encouraged her to include NOS objectives: "Think about why you need write objectives; Do you think all these objectives cover what you intent to teach through the lesson; think about including objectives on NOS" and for third lesson plan. The researcher warned her as: "What about including objectives on NOS".

She planned to teach "electricity" science content for grades seven and eight **for the fourth and fifth lesson plans.** She included NOS objectives in both lesson plans. In fourth lesson plan which was seventh grade, she included NOS objectives regarding empirical, creative and tentative NOS. The objectives she wrote were as followings: "Explain that scientists can not only make experiments but also observations to collect data", "State that scientists use their creativity to reach scientific knowledge" and she wrote objective for tentative NOS as "Specify the reasons of tentativeness aspect of NOS".

In **her fifth lesson** plan she planned to teach empirical, subjective NOS which were both stated in objective parts of the lesson plan and covered in description of activities part as well. The objectives she wrote were as followings: "State scientific knowledge depends on concrete data taken from observations or experiments" and "Identify scientist's backgrounds, training, and creativity affect their work".

In general, while all lesson plans were examined regarding NOS objectives, it could be summarized that she adopted more robust manner of including NOS objectives towards last two lesson plans. In her first, second and third lesson plans she did not include any objectives related to NOS aspects but she included NOS in description of activities part. However, towards the last lesson plans, she showed more consistency about including NOS in all parts of the lesson plan which were objective parts, description of activities part and evaluation part. In her fourth lesson plan she stated all NOS aspects in objectives part that she planned to teach in description of activities part. That is she included creative NOS, empirical and tentative NOS objectives and she also provided some instructional strategies in description of activities part as well. Similarly, in fifth lesson plan, she included objectives regarding empirical and subjective NOS which she also mentioned in description of activities part. The following table indicated the objectives that Ebru's stated in each lesson plan:

Table 58. NOS objectives in each lesson plan

# of lesson plans	Grade level	Science content	NOS aspects	NOS objective
1	7th	Atom models	-	-
2	8th	Formation of universe	-	-
3	8th	Heritage	-	-
4	7th	Electricity	Empirical NOS	Explain that scientists can not only make experiments but also observations to collect data
			Tentative NOS	Specify the reasons of tentativeness aspect of NOS
			Creative NOS	State that scientists use their creativity to reach scientific knowledge
5	8th	Electricity	Empirical NOS	State scientific knowledge depends on concrete data taken from observations or experiments
			Subjective NOS	Identify scientist's backgrounds, training, and creativity affect their work

-: indicated the absence of the subject

Additionally, interview and reflection paper were used as data source to understand her NOS instructional planning with regard to NOS objectives. At the end of the NOS intervention, participants were interviewed related to her perceived development of NOS instructional planning. Moreover, she also asked to write a reflection paper including points on her NOS teaching perception. In addition to lesson plan analysis, analysis of post interview and reflection paper supported her manner regarding instructional planning in terms of NOS objective writing. She confirmed that she did not write any NOS objectives at her first lesson plans due to her perception about the function of objectives in a lesson plan in response to interview questions:

E: At the beginning I did not think that we would write objectives for NOS and I did not write at the beginning.

R: Why not?

E: Actually it was a big mistake. Maybe I did not know much about the content of the lesson plan. I mean that may be I did not know why a lesson plan is written and how it is written. While the basic aim of lesson plans we wrote that teaching NOS by the help of HOS. Thus, absence of objectives related to them was a big lack.

Following section described participant's development of explicit reflective NOS instructional planning revealed through activities part of the lesson plans.

4.5.2.3. Development of lesson plans regarding NOS activities

That section of the "findings" part informed about in what ways and at what extent participant achieved to adopt explicit reflective approach to teach NOS in lesson plans**.** For instance, in her **first lesson plan,** she used a hands on activity combined with HOS which included pictures of atom models belonging to five different atom models, and information cards on each different atom model proposed by different scientists in history. Students were required to match pictures and information cards. Through the activity she also planned to teach NOS regarding tentative and subjective NOS. See below a sample from the lesson plan describing the activity:

"In this part the class will be divided into 5 parts and I will give them 5 different pictures belonging to different 5 atom models. At the same time I will give same written cards to each group. These written cards gave information about the different kinds of atom models… When exercise is finished I will make a brief summary about the lesson. Most importantly I will point the date of the atom models. Every model that has a different discoverer was found at a different time. Each model was developed and changed into another model. Moreover atom has a very long history. By looking this history, we can infer that science is subjective, tentative and includes creativity, imagination of the scientists because each scientist looked at same atom, and made different models. Moreover these models were changed in time. After making this summary, I will finish the lesson."

However, she did not connect the activity with how science/scientists work. That is she did not include any NOS related questions to provide NOS discussion and address NOS. Instead, she adopted lecturing of these NOS aspects at the end of the lesson while she was summarizing the whole topic. Additionally, she did not include any objective on NOS either.

Therefore, her instructional planning regarding tentative, subjective and creative NOS was categorized as *needs development.*

For the **second lesson plan**, her manner of teaching NOS was unclear. She included empirical, tentative and creative NOS within the context of formation of universe. For instance, for empirical NOS, she seemed to adopt more implicit manner of teaching it in her lesson plan. That is, she just gave an example without any further NOS emphasis and indicated that example implied empirical NOS. Since she did not include any NOS objective or NOS instructional prompts, her plan regarding empirical NOS categorized as *poor.* Sample of lesson plan part reflecting her manner of NOS teaching was presented below:

"…After listening to the ideas of all students, some information including the history of theories about universe formation will be given to the students: It is not very easy to understand completely how universe formed. There are numerous and different theories about this formation. Today the most widely accepted theory is the Big Bang theory. It was proposed between 1920 and 1930. There are three observations (observation aspect of NOS) which are the reasons of Big Bang Theory: Universe is expanding (1920s). Relative amounts of chemical elements in the universe (by experiments, empirically based)….."

Here she got alerted on including NOS instructional strategies to address empirical NOS in a more reflective way*: "*you need to ask questions or use other strategies to make student understand various aspects of NOS; or you just expect them to realize these aspects just from your instruction without an explicit emphasis"

Unlike to her manner of teaching empirical NOS, she was more reflective while teaching tentative NOS in the same lesson plan. She provided an example and showed efforts to connect it with NOS. She let students to express their ideas and tried to create a discussion environment:

"…After talking about the Big Bang, other theories will be talked. These theories are related to the formation of Universe which were by: out bursting from the Sun, by gas and dust cloud and by decaying of Jupiter…After giving the names of these theories **a** question will be asked: Do you think that in the future there may be different theories from these? Students will explain their ideas individually whether they think another theory will be found in the future. After their discussion it will be mentioned that there is a possibility of finding another theory that explains the formation of universe due to improving technology. By giving this information tentativeness aspect of the nature can be given…"

Additionally, at the end of the lesson she also wrapped up tentative NOS. She made a brief summary of tentative NOS by using an HOS example on formation of universe:

“It will be explained the most widely accepted theory is the Big Bang theory. The history of formation of universe will especially be emphasized. In time a lot of theories were found by different scientists. Scientists can always change their theories, laws, and observations etc. in time. For example, today we saw different theories about the formation of universe. One of them is widely accepted today. However, this may change in the future. This changing shows the tentativeness aspect of the nature of science…”

Although her efforts to be reflective for teaching tentative NOS in her lesson plan, she did not provide any objective regarding tentative NOS. Therefore, her instructional plan regarding tentative NOS was categorized as *needs development.*

For teaching creative NOS, she provided hands on activity, and she showed efforts to emphasize how the activity reflected how science works. Although she lacked of clear NOS questions to guide NOS discussion or related the activity with how science works, inclusion of specific instructional activity for NOS emphasis indicated efforts to be reflective in NOS instruction in lesson plan. However, she did not provide any objective on creative NOS. Therefore her instructional planning regarding creative NOS was categorized as *needs development*. Following sample of lesson plan indicated Ebru’s efforts of planned teaching of creative NOS:

“…….These two questions will be asked:

Which theory can be the most acceptable theory? Why?

Draw a model, picture etc. that shows theory that you support. (They can use colorful pens in their drawings). In the answers of this question, imagination and subjectivity aspects will be mentioned since each group will create a different model by using their own imagination. Moreover, all groups are at same level of knowledge about the topic. Therefore answers for the 1st question can be a representation for the subjectivity because groups will support different theories…Give the students 10 minutes to think about the questions and answer. After waiting 10 minutes, a discussion will be started in the class (4th objective). Each student will express his/her idea about the topic. Then the drawings will be stacked to the board. Each group will explain their drawings. By emphasizing the differences of models, it is tried to be given that during the formation of scientific models or knowledge, scientists use their creativity, prior knowledge, expectations etc…"

For the third lesson plan, she planned to teach Heritage as science content. Regarding NOS teaching, she showed implicit manner of NOS instruction. At the end of the lesson plan, she provided an example claimed to be related to empirical and tentative NOS without further NOS emphasize to address these aspects explicitly and reflectively. Instructor met with the participant to make clear explicit reflective NOS instruction to her after she turned in third lesson plan. Her instructional plan regarding empirical and tentative NOS was categorized as *poor* since she did not include any NOS objective or NOS instructional prompts either. See the sample of lesson plan below reflecting Ebru's planned teaching manner of empirical and tentative NOS:

"…Of course the concept of heritable was also not known in that time. By the help of improving technology people starts to find the reasons of these diseases such as hemophilia or anemia by making more clear observations or experiments (Tentativeness and Empirically-Based). In the past they did not see the intermarriages as a reason of heritable diseases but now people know relative marriages play very important role in these heritable diseases…"

She showed some improvements regarding NOS instructional planning in the **fourth lesson plan.** She planned to teach batteries in electricity science content. She showed explicit manner of NOS instructional planning through having NOS objectives such as empirical NOS, tentative NOS and creative NOS and also addressing them in the description of activities part of lesson plan as well. Additionally, she revealed reflective manner in her NOS instructional plan via providing NOS questions and specific examples to address NOS. However, her explicit reflective manner varied regarding NOS aspects. For instance, for teaching empirical NOS, she started lesson with some questions related to experiment in which she mentioned Volta Pile and Galvani Pile:

"…At the beginning of this part, some questions will be asked: According to you how did Volta make his pile? If students give the experiment as an answer, the second question will be asked: What is an experiment according to you? After they talk about this question, the third question will be asked: Do you think that scientists always make experiments to reach scientific knowledge?

During answering of this question, there may be a discussion among students due to their misconceptions about the NOS**.** Because there will be many students who say that scientists should make experiments during their works. After this discussion finishes, an example will be given to show that science does not have an obligatory including experiment. This example is related with today's topic which is Volta's pile…"

Here she provided NOS questions, and also gave space to students to express their ideas via discussion. Additionally, she showed efforts to create a discussion environment. Her instructional planning regarding empirical NOS was categorized as *exemplary*. The following was the sample of lesson plan reflecting Ebru's manner of teaching empirical NOS:

"…During answering of this question, there may be a discussion among students due to their misconceptions about the NOS….. After this discussion finishes, an example will be given to show that science does not have an obligatory including experiment….…Before Volta, Luigi Galvani (1737-1798) studied about this topic. By making some observations (empirically-based) he explained his 'animal electricity' hypothesis in 1971. In that hypothesis, he explained that when the nerves in the leg of a dead frog were cut, it was observed that the nerves contracted…………… I will connect the previous empirically-based part which is the observations made by Galvani and Volta's experiment. I will emphasize that scientists can make only observation or experiment or they can make both of them together to collect data….."

Regarding creative NOS, she also used HOS example which is about Volta's and Galvani's work. However, the provided example to address creative NOS was found to be inappropriate. She provided NOS questions and showed efforts to create NOS discussion. The questions that she provided to facilitate students' understanding on creative NOS were more appropriate for teaching of subjective NOS:

"….Then lesson will continue by talking about Volta. During this time, creativity aspect will be tried to be given by comparing Volta and Galvani. The information 'after Galvani explained his theory, Volta found the reasons of that contraction. The reasons were two different metals and including fluid of cells. Then he thought that to obtain electricity, there should be two different metals and fluid' will be given. After I give this information, I will ask that: What can be the reason of that Volta did not continue working on an animal cell like Galvani? After students give their answers, I will say that Galvani could not think in the same perspective with Volta. Volta might have more creativity than Galvani and so he thought that I did not need an animal cell to create an electric current, because he found the reason of the electric current…"

Since her example was more convenient to address subjective NOS, she was alerted to address subjectivity through that example: "Maybe it is more convenient here to talk about subjectivity; because both have different background (one of them doctor and the other is physicist) so they make different inferences and conclusions"

Due to her efforts to address creative NOS in objective and description of activities part, her instructional planning regarding creative NOS was categorized as *needs development.* On the other hand, her plan regarding tentative NOS was more reflective. She provided same HOS example which was related to Volta and Galvani, and connected HOS based example with NOS well. She provided questions and gave space students to discuss their ideas as well as addressed it in objective part of the lesson plan. Therefore, her instructional planning regarding tentative NOS was categorized as *exemplary.* See the lesson plan sample below reflecting Ebru's creative NOS teaching:

"...After giving this information, I will ask: Do you think that Galvani's hypothesis is still valid? And can scientific knowledge change in time? When students finish their talking about the questions, I will explain that after Volta's experiment, Galvani's hypothesis did not work anymore. Due to the fact that Volta's explanation was mostly accepted and he removed the animal electricity theory of Galvani. This shows the scientific knowledge can change in time (tentativeness). After this explanation, some questions will be asked: According to you how can scientific knowledge change in time? What can be the result(s) of this changing? Again in the explanations of these questions tentativeness aspect of NOS will be talked as by the help of improving technology, new findings, different point of views, scientific knowledge can change in time…"

In the **fifth lesson plan** she planned to teach bulbs in electricity science content. She kept same manner of teaching NOS in her lesson plan as the fourth lesson plan. She showed explicit manner of NOS instructional planning through having NOS objectives such as empirical NOS, and subjective NOS that were addressed in the description of activities part of lesson plan as well. Additionally, she revealed reflective manner in her NOS instructional plan via providing NOS questions and specific examples to address NOS. For instance, to emphasize subjective NOS, she adopted a different strategy which she used both content generic activity and HOS based example to address subjective NOS. First she planned to give a script on Edison's life and then relate this example with how science works:

“…A small part of reading again will be read: A team of talented workers assisted him all hours of the day and night. These men had the skills to make Edison's ideas and sketches into real devices of wood, wire, glass, and metal. Then another question will be asked: Why did not Edison’s workers find the incandescent light bulb, although they worked with Edison and so they saw everything that Edison made? Do you think that scientists can arrive different conclusions by looking at same object, data etc.? Can scientist’s backgrounds, training, creativity affect their work? Can you give examples about this being affected?”

After these prompting questions on subjective NOS, she planned to conduct a content generic activity to facilitate students’ understanding on subjectivity. The content generic activity was the “young of old” activity (Lederman et al 1998) in which students were shown a picture in which both a young or an old lady could be seen:

“…. Students will look at the picture and will tell what they see? Some of the students will see a young woman and other will see an old woman. It will be asked what you saw. Why did you see different face although you look at same picture? It is said that all of you look at same picture but you see two different women face. This situation is also valid for scientists. They can look at any data, object, or event at different perspectives. Because they have different backgrounds, training, creativity, etc...”

Providing specific instructional activities and questions to address subjective NOS made her planned instruction reflective. Additionally, including subjective NOS in objectives as well in *description of activities part* constituted for explicit subjective NOS instructional planning. In that sense she achieved subjective NOS instructional planning in an explicit and reflective manner and categorized as *exemplary.*

For instructional planning of teaching empirical basis in the same lesson plan, she planned to ask several questions and showed efforts to create discussion environment to discuss on empirical NOS. Similarly she used Edison’s life as a basis to start NOS discussion to address empirical NOS:

“…….In this part some questions will be asked to students: Which method did Edison use during his invention of the light bulb? (It is expected students will talk about his experiments). If they talk about experiment, there is no problem and second question will be asked. If they will not talk about experiment, I will orient them to the reading passage including that “During his most inventive years, Edison conducted experiments at his Menlo Park, New Jersey, laboratory”, Can you define what experiment is?, According to you do scientists always make experiments to collect data?, Do they [scientists] make observations? , Can you give example about how scientists make observations to collect data?, Do you think that scientific knowledge requires observation or experiment? I mean can scientists find scientific knowledge without concrete data? After they discuss these questions, a brief summary will be made: Scientific knowledge depends on concrete evidences which are taken by observations and experiments. Each scientist should support his/her idea with concrete data. Otherwise, nobody accept their findings. There is no obligatory that scientists always should make experiments. Sometimes they make observations to collect data for their study. For example; scientists make classification among living things by making only observations….."

Additionally, she seemed to adopt more student centered approach via giving space for student's expression of ideas and acted as a guide orienting students as seen from the lesson plan:

"…If they talk about experiment, there is no problem and second question will be asked? If they will not talk about experiment, I will orient them to the reading passage including that "During his most inventive years, Edison conducted experiments at his Menlo Park, New Jersey, laboratory…"

Having structured instructional prompts which provided students with opportunities to reflect on their activities and learning within a NOS framework made the instructional planning is reflective. Regarding explicit component of her planned NOS teaching, having NOS objectives and emphasizing them in description of activities part constituted as explicit NOS instruction. Therefore, her instructional plan regarding empirical NOS categorized as *exemplary.*

Overall, examination of her lesson plans indicated that she improved her instructional planning regarding NOS teaching. At first lesson plans she adopted either lecturing or implicit way of teaching NOS in her lesson plans. However her last two lesson plans included examples from HOS, guiding NOS questions to create environment in which students reflect on their ideas on science. Additionally, she was able to connect HOS based examples with NOS more successfully which gave opportunities of reflection for students. Specifically, she improved her instructional planning regarding empirical NOS, subjective NOS, and tentative NOS. The most aspects used in her lesson plans were tentative NOS (in four lesson plans), followed by empirical and creative NOS (in 3 lesson plans). Moreover, she achieved both explicit and reflective NOS instructional planning in the context of HOS for empirical, tentative and subjective NOS. She used content generic activities and HOS as a context to teach NOS, but she mostly used HOS to address NOS. Following table indicated each NOS aspect she planned to teach in activities part, and the instructional strategies she planned to use to teach NOS.

Table 59. Summary of NOS aspects addressed in description of activities part of lesson plan

# of lesson plan	**Grade level**	**Science content**	**NOS aspects**	**NOS teaching strategies**	**Explicit-Reflective**
1	7^{th}	Atom models	Subjective &Tentative& Creative NOS	Lecturing	Needs development
2	8^{th}	Formation of universe	Empirical NOS	HOS example	Poor
			Tentative NOS	HOS example	Needs development
			Creative NOS	Hands-on activity	Needs development
3	8^{th}	Heritage	Tentative NOS	HOS example	Poor
			Empirical NOS	HOS example	Poor
4	7^{th}	Electricity	Empirical NOS	HOS example	Exemplary
			Tentative NOS	HOS example	Exemplary
			Creative NOS	HOS example	Needs development
5	8^{th}	Electricity	Subjective NOS	HOS example Content generic activity	Exemplary
			Empirical NOS	HOS example	Exemplary

✓ : indicated the existence of the task, - : indicated the lack of task

At the end of the NOS intervention, participant was interviewed to get insights on their NOS teaching perception and development of NOS instructional planning. Interview included questions regarding preferences to teach NOS. Additionally, participants were asked to write a reflection paper on her perceptions of NOS teaching at the end of the study. Those data sources were used to support the findings revealed via lesson plan analysis. Analysis of responses to interviews and reflection paper supported her manner of NOS teaching approach in lesson plans. She stated in reflection paper, she would ask some NOS questions for instance in the context of HOS to address NOS in her teaching:

"…I think that all aspects of NOS can easily be given by using HOS. For example; when I look at only my lesson plans, I see that I can give all aspects in these lesson plans. Moreover, my friends also make some lectures. In these lectures, they can also easily show NOS."

Additionally, she stated in her reflection paper that she would avoid direct teaching of NOS instead she would prefer to use activities and some guiding questions and examples rather than direct teaching:

"I will always try to give examples and make activities to teach NOS. I think that direct teaching is not a proper way to teach NOS. Therefore, I always try to catch students' interest by asking questions such as:

- Do you think that scientists use their creativity and imagination? Can you give examples?
- Can technology affect your chemistry, biology, or physics lessons?
- Do scientists make observation to collect data?"

She mentioned same manner of teaching NOS in responses to interview too. She repeated that she would ask NOS questions, and activities. Additionally, she also stated that she would integrate NOS into science content:

E: I do not prefer to give the information directly. For instance, at the beginning of the term, if you only said "theory and law are different things, and these two things do not turn into one another", it did not make sense to me. I mean that maybe I would think it as you said that time but I could not explain the rationale of the situation. With the help of the activities and the guidance, we thought and said "yes, it is like that." The same thing is also valid for the lesson plans. Instead of only for instance, giving it directly, it is better to make students think through the activities. For instance, regarding subjective and tentative NOS, it is better to ask questions or giving examples instead of giving the direct definitions of these aspects. That is what I tried in my lesson plans which were integration of NOS as well."

Next, participant’s development in NOS assessment revealed through lesson plan analysis was presented.

4.5.2.4. Development of lesson plans regarding NOS assessment

That part of the findings section informed about Ebru’s efforts to evaluate NOS aspects that she planned to teach. The kind of assessment strategies that she used for each specific targeted NOS aspect was reported. Analysis of lesson plans indicated he adopted an NOS assessment approach towards last lesson plans. However none of the assessments she planned to make were specific to each NOS aspect targeted to teach. In her **first lesson plan**, she did not consider assessing NOS. However her **second lesson plan** included NOS assessment but she did not specify NOS aspects to be assessed. She planned to give homework such as: “Please write a reflection about the history of the formation of universe. Moreover indicate the nature of science aspects in your works…”

Unlikely to the second lesson plan, she did not include any evaluation for NOS in her **third lesson plan**. Thus, she was alerted on NOS assessment by the researcher. However her fifth and fourth lesson plans had NOS assessments in the form of homework and reflection paper. In fourth lesson plan, although she mentioned empirical, tentative and creative NOS in both objectives and description of activities part, she only asked students to exemplify tentative NOS as an assessment. For instance, in her fifth lesson plan she stated that she would give homework to assess students’ NOS understanding:

“…To evaluate students homework will be given to the students. This homework is given below: Please find an example which shows scientific knowledge can change in time and write the reason(s) of this changing.”

In her **fifth lesson plan,** she assigned reflection paper to the students. Distinctively, she stated that she expected students to write on empirical and subjective NOS which were both stated in objectives and description of activities part of the lesson plan*:*

“….At the end of the lesson, a reflection paper will be wanted. It is said that please write everything that you learned in this lesson. Not only think about Edison’s light bulb, but also the nature of the scientific knowledge. It is expected to be written empirically-based and subjectivity aspects of NOS. Students do not have to use “empirically-based” and “subjectivity” words but they have to talk about them.”

Following table indicated brief description of each NOS assessment strategy used in lesson plans:

Table 60. NOS assessment strategies used in each lesson plan

# of lesson plan	Science content	NOS aspects	NOS assessment strategies
1	Atom models	-	No NOS evaluation
2	Formation of universe	Not specified	Homework
3	Heritage	-	No NOS evaluation
4	Electricity	Tentative NOS	Homework
5	Electricity	Empirical NOS Subjective NOS	Reflection paper

-: indicates the lack of task

In general, Ebru adopted an assessment strategy specific to targeted NOS aspects towards the last lesson plans while she did not use any assessment for NOS or used more general strategies to asses NOS at first. Correspondingly, an interview conducted at the end of the study to understand her NOS teaching perception and development of NOS instructional planning with respect to NOS assessment as well. In her responses to interview, she also mentioned poster preparation and reflection paper as an assessment tool, although she did not use poster preparation in her lesson plans for assessment:

E: At the end of the course [science method course], for example, we wrote reflection papers. What we learned NOS in this lesson different than we learned in the physics, chemistry and biology. I would asses [NOS understanding] by giving articles or reflection papers as you did [in science method course]. For example, we prepared a poster. We read a lot of journal, discuss on which one we should do for this poster…I think that students can be improved in terms of aspects in this way…..

Subsequent section presented an overview of the participant’s development regarding NOS instructional planning.

4.5.2.5. General overview for NOS instructional planning

Generally, the analysis of lesson plans indicated Ebru's development of NOS instructional planning regarding NOS objectives, NOS activities and NOS assessment. She started to include NOS objectives which she mentioned in description of activities part and assessment part as well. Regarding activities, she included more NOS questions, showed efforts to initiate NOS discussions and gave more space to students to express their ideas in her plans. Additionally, she used HOS to address NOS. Her manner of planning was shifted to more explicit and reflective other than lecturing. Specifically, for teaching of subjective empirical and tentative NOS she adopted explicit and reflective manner of teaching NOS in her plans. Although she achieved informed understanding for all NOS aspects concerned in the study, she addressed subjective, creative, tentative and empirical NOS through all lesson plans. Yet, as mentioned above, she achieved explicit reflective instructional planning with respect to subjective, empirical and tentative NOS.

Regarding NOS assessment, her last two lesson plans included her manner of assessing NOS were shifted from general to more specified strategies. In addition to these, her last two lesson plans were more consistent regarding objectives, description of activities and assessment parts. That is, she stated the NOS objectives, she planned to provide explicit reflective instructional strategies for those aspects in description of activities part and also she planned to asses those aspects in evaluation part of lesson plan. The NOS aspects that she showed this consistency were subjective, empirical and tentative NOS. In other words, she achieved to have objectives of these aspects, planned explicit and reflective instructional prompts and assed them specifically as well. Following table indicated general overview of Ebru's instructional planning regarding objectives, description of activities and evaluation parts of the lesson plans was summarized in following table:

Table 61. Summary of overall NOS instructional planning

# of lesson plan	Grade level	Science content	NOS aspects	NOS teaching strategies	Explicit-Reflective	NOS objectives	NOS assesment
1	7th	Atom models	Subjective &Tentative& Creative NOS	Lecturing	Needs development	-	-
2	8th	Formation of universe	Empirical NOS	HOS example	Poor	-	✓
			Tentative NOS	HOS example	Needs development	-	✓
			Creative NOS	Hands on activity	Needs development	-	✓
3	8th	Heritage	Tentative NOS	HOS example	Poor	-	-
			Empirical NOS	HOS example	Poor	-	-
4	7th	Electricity	Empirical NOS	HOS example	Exemplary	✓	-
			Tentative NOS	HOS example	Exemplary	✓	✓
			Creative NOS	HOS example	Needs development	✓	-
5	8th	Electricity	Subjective NOS	HOS example & Content generic activity	Exemplary	✓	✓
			Empirical NOS	HOS example	Exemplary	✓	✓

✓ : indicated the existence of the task, - : indicated the lack of task

Following section will inform on participant's perceived source of development for NOS instructional planning.

4.5.3. Learning experiences contributing to the ability to integrate NOS into instructional plans

In general, Ebru's instructional planning for teaching NOS has been evolved in an explicit reflective manner which included NOS objectives, specific activities for teaching NOS and specific assessment strategies for assessing NOS. Researcher applied several strategies to improve participants' NOS instructional such as feedback to lesson plans, HOS based examples coupled with NOS explicitly followed by NOS discussions, and lesson plan presentations followed by NOS discussions as well. To understand the relative importance of these learning experiences, researcher conducted interview with the participants. Analysis of interview revealed that Ebru perceived lesson planning activity which included creation and presentation of the lesson plan, as the main source contribute to her ability to integrate NOS into instructional plans. She stated lesson plan presentations as an authentic teaching experience. Additionally, she also mentioned value of discussion followed by lesson plan presentations, and feedback:

R: As a researcher, I aimed to help you improve your NOS understanding and NOS instructional planning. For this reason, I applied several strategies such as giving feedback for lesson plans, providing HOS examples in class and asking you to prepare and present lesson plans, which was followed by class discussions. Which of these activities do you think influence your skills regarding NOS instructional planning?

E: Firstly, while preparing lesson plans, I needed to investigate and learn NOS better. Additionally, while presenting NOS lesson plans, I learned how to integrate NOS and teach NOS in an authentic class environment. For instance, regarding teaching subjectivity, presenting the lesson plan and feedback because of you and my friends I developed hugely my ability to teach subjectivity….but preparing lesson plans were the activity that impacted most on my ability to teach NOS. Because, preparing lesson plans required tedious work and it was all my responsibility to prepare it. It included responsibility of both learning and teaching [NOS]. Second, presenting lesson plans was also so important. It [lesson plan presentation] was served as an authentic learning opportunity. That is, while presenting it [microteaching] you might face some problems [regarding teaching NOS] that you need to solve immediately. Additionally, lesson plan presentations of other friends provided variety of examples which also contributed to my development of NOS instructional planning

4.6. CASE VI

The sixth case of the study was named Melis. The results were presented related to (1) how her NOS understanding changed in the context of explicit reflective HOS based approach, (2) how progress trajectory in relation to integrating NOS into her lesson plans occurred as a result of feedback in the context of explicit reflective HOS based approach, and (3) what learning experiences contributed to her ability to integrate NOS into their instructional plans.

4.6.1. Change in NOS understanding

Participant's NOS views on tentative NOS, empirical NOS, inferential NOS, creative NOS, Socio-cultural NOS, theory and law, as well as subjective NOS were presented in that section. Following section presented participant's tentative NOS views.

Tentative NOS: Prior to the NOS intervention, Melis showed inadequate view of tentative NOS. Participants were categorized as holding inadequate conceptions of tentative NOS, if they indicated that theories do change, but they indicated laws are certain, "true" and do not change. Correspondingly, Melis stated that theories could change, but laws could not change. However, she improved her tentative NOS understanding and showed informed view of tentative NOS over the science methods course. In her responses, she indicated that science could change through either accumulation of scientific knowledge or the replacement of previous scientific knowledge with the new one. Additionally, she also emphasized evidence and technological enhancements in development of scientific knowledge. She also highlighted that both scientific theories and laws changed too. Therefore, her view was categorized as informed view regarding tentative NOS at the end of the study (see table62 below for sample quotas).

Table 62. Melis's sample statements related to tentative NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	Laws cannot be changed. Theory can be changed. Theories cannot be changed, when they turn into laws. For instance evolution theory can be changed.
Post-VNOS-C	Informed	Yes science can change…for instance there are five different atom models and the models have changed in times. It was changed with improving technology and adding new knowledge to scientists previous knowledge…..Scientific knowledge change through as an accumulation of existing knowledge or removing the existing one and through totally constructing of new knowledge through new evidence …It [theory] can change because scientific knowledge is not absolute and subject to change… It [law] can change…

Subsequent section described participant's empirical NOS views.

Empirical NOS: Before NOS intervention, she revealed inadequate understanding related to empirical NOS. She considered experiments as procedural activity to prove scientific concepts and she disregarded role of evidence to support data. Yet, she recognized role of evidence to support claims and highlighted evidence to differentiate science from other disciplines at the end of the NOS intervention. Therefore, her view was categorized as informed view (see table63 below for sample quotas)

Table 63. Melis's sample statements related to empirical NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	Science is different from other disciplines, because it is objective Experiments are the procedural activity to prove truthiness of a condition. Experiments involve certain steps that scientists follow… in science people try to prove the reasons of some events. If they [reasons of events] are not proved with some experiments how we accept the truth of that event.
Post-VNOS-C	Informed	NOS make science different from other disciplines….. For example in science we support our ideas with experiments or observations… [in science] data is gathered through experiments and they are inferred. We have evidence [in science]. ….however in religious or philosophy we cannot support our ideas such as existence of god.

Participant's inferential NOS views were presented below.

Inferential NOS: Melis showed inadequate view of inferential NOS at the beginning of the intervention. She believed that science is "what we see", and she failed to recognize that scientists actually make sense of "what they observe". That is, she held the view that natural phenomena were directly accessible to the human senses. For instance, in her responses related to the existence of the dinosaurs, she expressed that fossils proved the existence of the dinosaurs. However, she shifted her understanding toward informed view of inferential NOS at the outset of the intervention. She recognized that scientists make inferences based on observations. For example, she explicitly referred that scientist made inferences based on their observations and supported her view with an example. Additionally, in her response to the VNOS-C-C question related to the existence of the dinosaurs, she also stated that scientists made conclusions based on the fossils (see table64 below for sample quotas).

Table 64.Melis's sample statements related to inferential NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	.. [to decide existence of dinosaurs] They [scientists] proved the existence of dinosaurs with finding and examining fossils.
Post-VNOS-C	Informed	.. They [scientists] make inferences according to their observations. For instance, astronauts cannot do experiments but they do observations and make inferences based on their observations. .. [to decide existence of dinosaurs] Scientists know their [dinosaurs'] existence with fossils records. Scientist made dinosaurs' models according to bigness and shapes of fossils…

Following section displayed participant's creative NOS views.

Creative NOS: Before NOS intervention, she indicated her awareness related to role of scientists' imagination and creativity in development of scientific knowledge. She recognized that scientist used their creativity and imagination while conducting scientific investigations. Nevertheless, she appreciated influence of imagination and creativity of scientists only at certain parts of scientific investigation. In her responses, she specifically outscored planning part of the scientific investigation that scientists' imagination was involved most. On account of she did not deny the role of creativity in development of scientific knowledge, her view was categorized as adequate. Yet, she shifted her understanding toward informed view of creative NOS understanding at the end of the intervention. As an indication view of informed view of creative NOS, she recognized the role of scientists' imagination and creativity for every phase of scientific investigation (see table65 below for sample quotas)

Table 65. Melis's sample statements related to Creative NOS revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Adequate	… When they [scientists] try to find and answer of an investigation they [scientists] are of course use their imaginations. With using their creativity, scientists make hypothesis and check the truthiness of that hypothesis with experiments. They [scientists] use their imagination in planning.
Post-VNOS-C	Informed	Scientists use their creativity in every step of scientific investigation. For instance, while stating a model or while design an experiment or to collect data [scientists use imagination and creativity].

Participant's views on socio cultural NOS explained below.

Socio Cultural NOS: At the beginning of the intervention, Melis revealed inadequate understanding of socio cultural NOS. She believed science as a discipline which is detached from the norms and values of culture in which it was practices. She indicated science as universal. But, she shifted her view toward informed view at the end of the intervention. She articulated that science was influenced by the cultural values of society and she also supported her view with an example related Aristotle's case (see table66 below for sample quotas).

Table 66. Melis's sample statements related to socio-cultural NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	I think science is universal because we all live in the same world. An event which may occur in the other side of the world may affect us…
Post-VNOS-C	Informed	Science reflects social and cultural values. …..Scientists' socio cultural environment in which they live, can affect their works. For instance Aristotle's was a religious person and so he thought that people were most important creatures in universe, so he said that earth is the center of universe.

Following section presented participant's views on function of theories and laws.

Theory &Law: Melis held the misconception that theories were less reliable than laws, and laws were more certain since they were proved. She stated theories as confirmed hypothesis, and laws as rule of unchangeable things. Still, she developed an informed view of theory and law at the end of the intervention. That is she appreciated role and function of theories and laws. She could be able to describe theories as explanatory and laws as descriptive (see table67 below for sample quotas)

Table 67. Melis's sample statements related to Theory &Law revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	… They [theories] cannot be changed if they become law. Theory is the confirmed hypothesis, but it is not exact. Law is the rule of unchangeable things. Laws cannot be change…For instance; the evolution theory can be changed because the exact reason [reason for evolution] is not known exactly.
Post-VNOS-C	Informed	Theory is the explanations of natural phenomena. …..Law explains the relationship between some phenomena….Scientific law explains relationships while scientific theories gives explanations related to phenomena.

Subsequent section described participant's subjective NOS views.

Subjective NOS: Melis showed inadequate understanding of subjective NOS at the beginning of the NOS intervention. She could not recognize role of scientist's' subjectivity while conducting scientific investigations and making scientific propositions. For instance, in her response related to the dinosaur extinction controversy, she explained the existence of various theories based on the occurrence of the event that the dinosaur extinction happened in ancient times and because of that scientists were not sure about the reasons. However, she came to belief that scientist's interpretations would vary because of personal backgrounds, perceptions, pre conceptions and expectations at the end of the intervention. In her responses to post VNOS-C-C, she stated clearly that because of scientists' subjectivity, they could infer same data set differently. Thus, her view was categorized as informed view (see table68 below for sample quotas)

Table 68. Melis's sample statements related to Subjective NOS revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	.... [regarding different theories on extinction of dinosaurs]At the ancient times, lots of events had there occurred which damaged the world. Scientists are not sure about the reasons [of disasters], even they look at same data. Thus scientists make their own comments [related to disasters] which are logical for them.
Post-VNOS-C	Informed	Science includes subjectivity aspect of science. Scientist look at same events and an object but they can infer different conclusions. It is related to their prior knowledge, pre-conceptions and socio cultural environment which they live. All of these aspects can affect their work.

In general, prior to intervention, participant revealed inadequate views on all NOS aspects except creative NOS which she showed adequate view. At the end, she shifted all her NOS views toward informed view on all aspects of NOS. Following section will inform on participant's progress on NOS instructional planning, and the sources of her development for NOS instructional planning.

4.6.2. The progress trajectory in relation to integrating NOS into lesson plans

Current part informed on participants' development of NOS instructional planning through following sub sections; general information about instructional planning, development of lesson plans regarding NOS objectives, development of lesson plan regarding NOS activities, development of lesson plan regarding NOS assessment and general overview of her NOS instructional planning. Next section provided general information related to Melis's instructional planning.

4.6.2.1. Information about instructional planning in general

Participant handed in four lesson plans and she did not turn in second lesson plan. She planned to teach science content such as digestive system (7th grade) in her first lesson plan, atom models (grade7) in her third lesson plan, Evolution (Heritage) (grade 8) in her fourth lesson plan, and Magnetism (grade 8) in her last lesson plan. Similar with the other participants, she chose all the science content that she planned to teach from Turkish science curricula which was available online. It was her responsibility to choose any science content from curriculum and adapt or modify it to address NOS explicitly. While creating lesson plans, she was in charge with the writing of objectives part of the lesson plan in which she stated the planned goals of her lesson, description of activities parts in which planned instructional strategies, tools were described to achieve the planned goals and lastly, evaluation part of the lesson plan, in which planned strategies were described to evaluate the planned goals. Since all participants were required to teach NOS in their lesson plans, they were expected to adapt and design lesson plans in which they address NOS explicitly. Subsequent section presented participant's development of lesson plans regarding NOS objective writing.

4.6.2.2. Development of lesson plan regarding NOS objectives

Objectives part of the lesson plans were more related with whether participants had the intention of teaching NOS explicitly/consciously. Inclusion of NOS objectives mostly indicated how they perceived teaching NOS e.g. they recognized NOS as an add-on, topic or as an important issue as the other science content to be taught/planned explicitly. Analysis of the lesson plans showed that Melis provided NOS objectives in all last three lesson plans but not in the first one. In her **first lesson plan**, although she showed some efforts to address NOS in description of activities part, she did not include any NOS objectives.

Therefore she was reminded about the function of objectives part and why one needed to write objectives. She did not hand in her second lesson plan.

For the **third lesson plan** in which she planned to teach atom models she included general NOS objective covering tentative, creative and subjective NOS. That is, for tentative, creative and subjective NOS, she wrote a general objective covering all three aspects in one objective. The objective she stated in her lesson plan was: ‟Explain the some aspects of NOS which are tentativeness subjectivity and creativity”. The researcher suggested her to write different objectives for each NOS aspect in her lesson plan as a feedback.

In the fourth lesson plan, she planned to teach evolution and also included objectives on tentative, and subjective NOS. Additionally, she took into account the feedback given in previous lesson plan and stated all objectives separately. Although she mentioned Theory & Law in description of activities part, she did not include any objective about it. Regarding tentative NOS, she wrote two objectives as ‟Explain that the scientific knowledge can change in time” and “Explain the fact that theories are not absolutely correct”. Regarding subjective NOS, she wrote objective as “Describe that scientists’ belief and prior knowledge can affect their work”.

In **fifth lesson plan**, she planned to teach magnetism. She provided objectives on subjective and empirical NOS whıch were as: “Explain the fact that scientists’ prior knowledge, preconceptions, socio- cultural environments which they live can affect their work.” Regarding empirical NOS, she wrote objective as “Describe that scientists can make experiment to support their works.”

In general, while all four lesson plans were examined regarding objectives, it could be summarized that she adopted robust manner of including NOS objectives. In her all lesson plans, she directly targeted NOS aspects. Looking through the frequency of NOS objectives, the most stated NOS aspect was subjective NOS in three lesson plans. The following table depicted the objectives that Melis stated in each lesson plan:

Table 69. NOS objectives in each lesson plan

# of lesson plans	Grade level	Science content	NOS aspects	NOS objective
1	7th	Digestive System	-	-
2	NA	NA	NA	NA
3	7th	Atom Models	Tentative NOS& Creative NOS& Subjective NOS	Explain the some aspects of NOS which are tentativeness subjectivity and creativity
4	8th	Evolution	Tentative NOS	Explain that the scientific knowledge can change in time Explain the fact that theories are not absolutely correct
			Subjective NOS	Describe that scientists' belief and prior knowledge can affect their work
5	8th	Magnetism	Empirical NOS	Describe that scientists can make experiment to support their works
			Subjective NOS	Explain the fact that scientists' prior knowledge, preconceptions, socio- cultural environments which they live can affect their work

-: indicated the absence of the subject, NA: not applicable

In addition to lesson plan analysis, data from post interview and reflection paper were used to back up the findings from lesson plan analysis. At the end of the study, participant was interviewed and asked to write reflection paper to understand her perception of NOS teaching, and her development regarding NOS instruction. The analysis showed her manner on including NOS objectives in her NOS instructional planning. She stated that she did not consider writing NOS objectives at first but then she started to include some objectives on NOS in response to interview:

R: Could we talk about the NOS objectives you wrote?

M: At the beginning of the semester, when I examined curricula, I did not see much about NOS objectives. Because of that I did not any NOS objective, instead I thought it was enough just to mention it while you teaching it. But towards my last lesson plans, I started to emphasis NOS in objectives part of my lesson plan.

Additionally, she also stated that NOS objectives should be included but she concerned about students' attitudes about it due to the fact that it was not included in science content and national examination content:

M: …honestly, I would integrate NOS [regarding NOS objectives]. But, students are responsible for a nationwide exam. They [students] could say this [NOS] is not included in the content of that nationwide exam, so I do not want to learn it [NOS]. I would integrate NOS into content, but attitudes of the students show that I should not address NOS [because of the nationwide exam].

Following section described participant's development of explicit reflective NOS instructional planning revealed through activities part of the lesson plans.

4.6.2.3. Development of lesson plans regarding NOS activities

That section of the "Findings" part informed about in what ways and at what extent participant achieved to adopt explicit reflective approach to teach NOS in her lesson plans. For instance, in her **first lesson plan,** she planned to teach digestive system and she planned to cover tentative and creative NOS. Although she planned to teach atom models through creative drama activity, she preferred to emphasize creative and tentative NOS through direct teaching without any space for student reflection, NOS questions or NOS discussion. But, she enriched her direct instruction for NOS with an example from HOS. Following sample part from her lesson plan illustrated the part of her planned tentative NOS teaching:

"….After each group play their roles, I will start the direct instruction. I will explain the each part of the digestive system. While I explain these, I will use history of digestive system to show and emphasize students that the one of the characteristic of nature of science is tentativeness because I want to embedded the NOS and HOS in my every lesson. Firstly, I will ask about that how the location of organs is determined in history and how the location of organ models is demonstrated in different way. I will wait them to answer my questions. Then, I will show these 3 pictures and I will say that as you see form these pictures some of the organs location are different from recent locations……..However, with improvement of technology, scientists have more advantages to investigate something and they change the model of organs. This shows us that the science is tentative and this is the aspect of nature of science….."

She kept similar manner for teaching creative NOS in her plan:

"….First picture was from 15th century and the second picture was from 16th century and as you see scientists at that time demonstrated the location of organs in that way, because at that time they did not have enough equipment to determine the exact locations of organs and they demonstrate like that. So, they used their imaginations and creativity to demonstrate the location of organs and this is the one aspect of NOS which is creativity…"

Therefore she was warned about focusing on how science scientists work, and asking NOS questions by the researcher: "Try to get that answers[ideas] from students instead of directly saying them [answering the questions related to NOS by yourself]…..you should emphasis on how scientists work and what science is…"

Moreover, she wrapped up NOS issues at the end of the lesson very briefly:

"….I will ask students about what they have learned today. I will ask them to describe their learning with a sentence. With this method, I will understand how much they learn about the lesson and at what level I will achieve the objectives. After I summarize the lesson like that way I will make a quiz to measure their learning. Also, I will emphasize tentative and creative aspects of nature of science for this lesson…"

In general, her instructional planning were found to be as lack of explicit reflective component since she did not provided neither NOS objectives for both aspects or NOS instructional prompts but direct teaching of these aspects. Thus, her lesson plan regarding tentative and creative NOS categorized as *needs development.*

As mentioned earlier she did not hand in her second lesson plan. **In the third lesson plan,** she planned to teach tentative, subjective and creative NOS in the context of atom models. However, although she claimed to cover all these three aspects in her lesson plan, she just emphasized tentative NOS explicitly and reflectively, but she failed to include subjective and creative NOS in the description of activities part of the lesson plan. Regarding tentative NOS, she planned to apply hands on activity throughout creative drama and HOS. She planned to give some information cards which included brief information on different atom models. Then, she asked students to create a role-play based on information on their cards. After the play, she provided some NOS questions to start discussion on creative NOS:

"…After I give note cards to each group, I will want them to create a role play related to their note cards. In addition, I will want them to draw a model related to their models on the board.

I will give 10 minutes to create a role-play. After each group finish their playing and drawing models on the boards, I will ask questions related to models them. Here are the questions: What was the historical order of atom models? What do you think that why there were 5 models related to the atom, who was the first scientist working on atom models? What was his contribution to atom models? And how do you interpret the meaning of different atom models?”

Different from her first lesson plan, here she tended to give more space for students’ reflections. That is, she specifically stated that she would wait for students’ answers, in addition to questions targeting NOS:

“Firstly, I will wait them to answer my questions and if they don’t, I will help them to answer…”

Additionally, she also provided possible answers to her questions which provided more detailed structure of lesson plan and the way she addressed tentative NOS:

“… Here are the answers of questions: Historical order is that: Dalton atom model (1803), Thomson atom model (1904), Rutherford atom model (1911), Bohr atom model (1913) and Electron cloud model (1926). The reason of different models is that each model was the correct form of the previous one. That is, for instance, Bohr corrected the mistake [of by refuted] Rutherford. With improving technology, and communication of scientists with each other, [they] corrected the wrong points of these models. They could look at atom in more meaningful aspect with each improving model, so there are five models. Dalton is the first scientist to work on atom. Actually, he made the bases of atom theory. He found the most important point of atom which was the all matter is composed of atoms. The latter scientists started their working on bases of the Dalton atom model. ……Different atom models show us that the scientific knowledge can change. With improving technology or addition of new knowledge, the models can change and this show us the tentative aspect of the NOS”

Although she achieved explicit reflective NOS instructional planning regarding tentative NOS, she did not include any instructional prompts within the flow of lesson plan regarding creative or subjective NOS. Instead, throughout an implicit manner she assumed some examples would lead students understand these aspects. For instance, regarding creative NOS, she assumed the information on note card would facilitate students understanding on creative NOS. However, she did not include any NOS questions to emphasis NOS explicitly and reflectively:

"…Thomson Atom Model: He assimilated atom model to plum-pudding. (Creativity aspect of NOS)"

Absence of these aspects (subjective and creative NOS) in the description of activities part did not make her instruction implicit since she at least stated subjective and creative NOS into objectives part. Yet, due to lack of reflective component, her plan regarding subjective and creative NOS was categorized as *needs development*.

Regarding **fourth lesson plan,** she planned to teach evolution which was presented under the cell division and inheritance content in eighth grade science curriculum. Additionally, she covered subjective and tentative NOS. Regarding subjective NOS, first, she provided some questions to initiate NOS discussion on subjective NOS. Due to inclusion of subjective NOS objective and instructional prompt, her lesson plan regarding subjective NOS was "*exemplary"*. For instance, she started questions on Lamarck's theory of evolution then connected it to subjective NOS:

"…Here are questions; how did Lamarck constitute his theory of evolution? What do you think about 'Lamarck incorporated this belief [his conceptions related to spontaneous generation] into his theory of evolution, along with other more common beliefs of the time?' Can scientists' beliefs and preconceptions affect their work? Explain it with examples."

Then, she provided the content generic activity. She provided a picture which could be seen either as a picture of vase or picture of side faces and asked students what they saw:

"During this question, I will show a figure to students and I will ask them what they see from this figure. I think some of them see 2 people and some of them see vase… I will say at this point 'As you see some of you see vase and some of you see two people. You look at the same picture and see different things. Scientists also can look at an event at different aspects and this can affect their work. This is like working stills; some of you like working with writing and other like with reading or listening. The same is true for scientists. Their prior knowledge, working stills, expert areas and cultures different from each other, so these affect their working…"

To cover tentative NOS, she gave a reading script including information from HOS. She provided some information comparing Lamarck's and Darwin's evolution theory. Then, she provided some questions related to tentative NOS and theory & law. She provided questions from the script first, then moved forward to questions related to theory & laws and tentative NOS. She stated following questions in her lesson plan to address these NOS aspects:

“What can you infer about why August Weismann rejected the Lamarck’s theory?

What was the reason of rejection of Lamarck’s theory?

Can you define what does theory means?

Is there any difference between theories and laws?

Do you think that theories can change over time?

Can you give examples to changing theories?

What can be reasons of change of a scientific knowledge?”

Although she combined theory &l aws and tentative NOS in her plan, she only mentioned tentative NOS in objectives part of the lesson plan. In that sense, her plan regarding tentative NOS was explicit and reflective, but it was lack of explicit and reflective regarding theory &law, and needed to be developed. Thus, her plan regarding tentative NOS was categorized as “*exemplary*” while her plan regarding theory & law categorized as “*needs development.*

Her **fifth lesson plan** was related to magnetism topic. Regarding NOS issues, she covered subjective and empirical NOS in her plan. She also included these aspects in objectives part of the lesson plan as well. She provided an article related to life of William Gilbert who made important contributions to discovery of magnetism and electricity. Then she asked students read the article and asked some questions related to article and NOS. She provided following questions in her lesson plan:

“After students finish their reading I will ask some questions related to article. Here are questions:

Was William Gilbert affected from prior knowledge in his work?

What did cause the William Gilbert’s founding of magnetism?

Can scientists be affected from prior knowledge and preconceptions in their works?

Can socio-cultural events or structure affect scientists' works?

Are scientists objective or subjective in their works?

How did William Gilbert find the magnetism?

Do scientists have to make experiments to find something?

How can you support your hypothesis or solution of a problem other than experimentation method?

After, I finish the questioning part; I will come to end of the lesson…"

Here, she related article with empirical and subjective NOS. However, she only provided the questions, and did not provide any clue on how questions targeted to specific NOS aspects. Additionally, she did not wrap up or give any clue on how she would manage the discussion. Therefore, her lesson plan related to empirical and subjective NOS planning was categorized as "*needs development*"

In general, overall examination of her lesson plans indicated that she improved her instructional planning regarding "description of activities" part. At first she tended to use direct instruction but starting from fourth lesson plan, she used HOS as a context to teach NOS and combined HOS examples with NOS questions to create environment in which students reflect on their ideas on science. Distinctly in her third lesson plan she used hands on activity to emphasis NOS. Similarly, in her fourth lesson plan she also included content generic activity to address NOS, in addition to HOS based reading scripts. Specifically she achieved explicit reflective NOS instruction for tentative and subjective NOS. The most used NOS aspects were tentative and subjective NOS used in three lesson plans which she also employed explicit reflective instruction for these aspects.

Following summarized the instructional strategies and NOS aspects she used in description of activities part of the lesson plan:

Table 70. Summary of NOS aspects addressed in description of activities part of lesson plan

# of lesson plan	Grade evel	Science content	NOS aspects	NOS teaching strategies	Explicit-Reflective
1	7th	Digestive system	Tentative NOS	HOS-Direct instruction *Wrap up at the end of the lesson	Needs development
			Creative NOS	HOS-Direct instruction *Wrap up at the end of the lesson	Needs development
2	NA	NA	NA	NA	NA
3	7th	Atom models	Tentative NOS	Hands on activity/HOS	Exemplary
			Creative NOS	No emphasis/Example	Needs development
			Subjective NOS	No emphasis	Needs development
4	8th	Evolution (Heritage)	Subjective NOS	Content-generic activity	Exemplary
			Tentative NOS	HOS reading script/NOS questions	Needs development
			Theory &Law	HOS reading script/NOS questions	Needs development
5	8th	Magnetism	Subjective NOS	HOS reading script/NOS questions	Needs development
			Empirical NOS	HOS reading script/NOS questions	Needs development

✓ : indicated the existence of the task, - : indicated the lack of task, NA: not applicable

In addition to lesson plans, interview and reflection paper were also used as data source to understand participant's explicit reflective NOS instructional planning. Participant was interviewed related to her teaching perceptions of NOS and her development of NOS instructional planning at the end of the NOS intervention. Moreover, she also wrote reflection paper related to her NOS teaching at the end of the study. Analysis of reflection paper and interview also supported her manner of NOS instructional planning. When she asked how she would teach NOS, she stated that she would teach NOS explicitly via questions and HOS based reading scripts in the context of HOS as revealed through lesson plan analysis in responses to both interview and reflection paper. For instance in her interview she underscored addressing NOS through questions:

R: How would you teach NOS to the students, in what ways?

M: I would give reading scripts [HOS based]. I would ask questions such as do you think science is subject to change, it was changed at past, do you think still it could be changed, what is the difference between theory and law. Moreover, I would animate scientists' life to address NOS.

Her responses to interview questions were also supported with her statements in reflection paper too*:*

"I will teach and also I think that I will ask them in exams by giving articles. I think to teach NOS aspects with giving articles and I will want them to interpret them. Also, I will give scientists life and I will want them to create a play related to it. And then I will want them to interpret the events."

Next, participant's development in NOS assessment revealed through lesson plan analysis was presented.

4.6.2.4. Development of lesson plans regarding NOS assessment

That part of the findings section informed about Melis's efforts to asses NOS aspects that she planned to teach. The kind of strategies that she used for each specific targeted NOS aspect was reported. Analysis of lesson plans indicated that she started concerning about assessing NOS towards last lesson plans. In her first lesson plan, she did not provide any specific assessment strategy for NOS. However, she stated she would wrap up the NOS aspects which were tentative and subjective NOS for the first lesson plan at the end of the lesson:

"…Also I will emphasize tentative and creative aspects of nature of science for this lesson and I will explain that everything in our world is discovered with using of science process skills".

She kept similar manner for the third lesson plan regarding NOS evaluation. In her **third lesson plan,** she did not specify any strategy to assess students' knowledge of NOS. However, she only stated that she would ask students what they learned, and then she would decide if she achieved the lesson's objectives. Thus, she was reminded to specify strategies for assessment and be specific about NOS assessment. Following sample part from her lesson plan illustrated her manner of NOS assessment:

"I will ask students about what they have learned today. I will ask them to describe their learning with a sentence. With this method, I will learn at what level they learn about the lesson and at what level I will achieve the objectives. Then, I will summarize the lesson and finish the lesson."

In her fourth and third lesson plan, she showed some efforts to evaluate the targeted NOS aspects. For instance, in her **fourth lesson plan,** she stated she would ask student to prepare homework on tentative nature of theories and laws, and subjective NOS. However, she did not include any specific assessment strategy regarding function and difference of theory & law, although she addressed this aspect in description of activities part. See below the sample part from her lesson plan related to the assessment:

"…I will give students homework. It would be related to finding examples to changing theories and laws and found examples to scientists whose beliefs, preconceptions, socio-cultural environments affect their scientific work…"

Regarding her **fifth lesson plan,** she included empirical and subjective NOS in objectives, description of activities and evaluation part as well. Concerning assessment of these aspects, she stated she would want students to prepare homework specifically on empirical and subjective NOS:

"…I will learn at what level I will achieve the objectives and which objectives I am not able to give. I will give students homework. It would be related finding examples of some other methods other than experimentation that scientists used while investigating. Find events from the history which affect scientists to find some concept as in the case of William's exploration of magnet."

In general, although she did not think of evaluating NOS understanding of students in her first two lesson plans, she developed a homework strategy for NOS evaluation towards last two lesson plans. Moreover, she adopted an assessment strategy specific to the NOS aspects. That is, she stated content of homework for each targeted NOS aspects. In addition to lesson plan analysis, interviews related to participant's NOS teaching perceptions and her development of NOS instructional planning also supported her manner of assessment revealed in fifth and fourth lesson plans. She stated she would give homework in which students required to indicate NOS aspects:

R: What do you think of your NOS assessment?

M: At first, I did not assess NOS in my lesson plans. But towards last lesson plans, I started to give homework to evaluate NOS aspects.

Following table indicated brief description of each NOS assessment strategy used in lesson plans:

Table 71. NOS assessment strategies used in each lesson plan

# of lesson plan	Science content	NOS aspects	NOS assessment strategies
1	Digestive system	-	No NOS evaluation
2	NA	NA	NA
3	Atom models	-	No NOS Evaluation
4	Evolution (Heritage)	Tentative NOS	Homework
		Subjective NOS	Homework
5	Magnetism	Empirical NOS	Homework
		Subjective NOS	Homework

-: indicates the lack of task, NA: not applicable

In general, Melis adopted an assessment strategy specific to targeted NOS aspects towards the last lesson plans while she did not use any assessment for NOS or used more general strategies to asses NOS at first. Correspondingly, an interview conducted at the end of the study to understand her NOS teaching perception and development of NOS instructional planning with respect to NOS assessment as well. In her responses to interview, she also mentioned poster creation and reflection paper as an assessment tool, although she did not use poster creation in her lesson plans for assessment:

E: At the end of the course [science method course], for example, we wrote reflection papers. What we learned NOS in this lesson is different than we learned in the physics, chemistry and biology. I would asses [students' NOS understanding] by giving articles or reflection papers as you did [in science method course]. For example, we prepared a poster. We read a lot of journal, discussed on which one we should do for this poster…I think that students can be improved in terms of aspects in this way…..

Subsequent section presented an overview of the participant's development regarding NOS instructional planning.

4.6.2.5. General overview for NOS instructional planning

In general, analysis of lesson plans indicated Melis's development of NOS instructional planning regarding objectives, description of activities and evaluation. Regarding NOS objective, although she did not include any NOS objectives for her first lesson plan, she provided NOS objectives for the rest of the lesson plans. Regarding description of activities part, she shifted her direct teaching manner towards more explicit and reflective manner. That is, she provided some hands on activities such as content generic NOS activities and HOS examples to emphasize NOS. Additionally, she provided NOS questions to initiate NOS discussions. She mostly used HOS scripts and NOS questions to emphasize NOS. Specifically, for teaching subjective and tentative NOS she achieved explicit reflective NOS instruction in her plans. Concerning her NOS views, she displayed informed views for all NOS aspects at the end of the study, and she showed efforts to address generally tentative, creative, empirical, subjective NOS and function of theories and laws. However, as mentioned above, she only achieved explicit reflective NOS instructional planning for subjective and tentative NOS. Regarding NOS assessment, she assessed NOS aspects in her last two lesson plans. She provided homework as an assessment strategy for NOS aspects. In addition to these she showed more consistent manner of NOS instructional planning. That is, she stated NOS objectives, and she planned explicit reflective activities for those aspects in description of activities part and also she planned to assess these aspects as well. The NOS aspects that she revealed that consistency exists were tentative, subjective and empirical NOS in her lesson plans. Following table indicated general overview of Melis's instructional planning regarding objectives, description of activities and evaluation parts of the lesson plans was summarized in following table:

Table 72. Summary of overall NOS instructional planning

# of lesson plan	Grade level	Science content	NOS aspects	NOS teaching strategies	Explicit-Reflective	NOS evaluation	NOS objectives
1	7th	Digestive system	Tentative NOS	HOS-Direct instruction Wrap up at the end of the lesson	Needs development	-	-
			Creative NOS	HOS-Direct instruction Wrap up at the end of the lesson	Needs development	-	-
2	NA	NA	NA	NA	NA	NA	NA
3	7th	Atom models	Tentative NOS	Hands on activity/HOS	Exemplary	-	✓
			Creative NOS	No emphasis	Needs development	-	✓
			Subjective NOS	No emphasis	Needs development	-	✓
4	8th	Evolution (Heritage	Subjective NOS	Content-generic activity	Exemplary	✓	✓
			Tentative NOS	HOS reading script/NOS questions	Needs development	✓	✓
			Theory &Law	HOS reading script/NOS questions	Needs development	✓	-
5	8th	Magnetism	Subjective NOS	HOS reading script/NOS questions	Needs development	✓	✓
			Empirical NOS	HOS reading script/NOS questions	Needs development	✓	✓

✓ : indicated the existence of the task, - : indicated the lack of task, NA: not applicable

Following section will inform on participant's perceived source of development for NOS instructional planning.

4.6.3. Learning experiences contributing to the ability to integrate NOS into instructional plans

In general, Melis's instructional planning for teaching NOS has been evolved in an explicit reflective manner which included NOS objectives, specific activities for teaching NOS and specific assessment strategies for assessing NOS. Researcher applied several strategies to improve participants' NOS instructional such as feedback to lesson plans, HOS based examples coupled with NOS explicitly followed by NOS discussions, and lesson plan presentations followed by NOS discussions as well. To understand the relative importance of these learning experiences, researcher conducted interview with participants. Analysis of interview revealed that Melis perceived feedback given by the researcher to her lesson plans, and follow up discussions after peer presentations as the main source contributing to her ability to integrate NOS into instructional plans:

R: As a researcher, I aimed to help you improve your NOS understanding and NOS instructional planning. For this reason, I applied several strategies such as giving feedback for lesson plans, providing HOS examples in class and asking you to prepare and present lesson plans, which was followed by class discussions. Which of these activities do you think influence your skills regarding NOS instructional planning?

M: Discussions and feedback were the activities contributed most to the development of my NOS instructional planning… if I rated it, first of all feedbacks that given to our lesson plans contributed most and then discussions were the second one contrıbuted to my development.

R: Why do you think so?

M: I did not anything about NOS initially. We started to learn NOS while trying to integrate NOS [in lesson plans]. I did not know about how to do it at first. But later, I improved myself by means of integrating NOS owing to your feedbacks. ..For instance, your feedbacks like "use subjectivity aspect in this way…you could connect that NOS aspect (e.g. through this question etc.) contributed the way I created next lesson plan.

Additionally, the discussions related to NOS lesson plan presentations (e.g. what other NOS aspects could be integrated or How NOS aspects could be better integrated) contributed to my NOS instructional planning.

4.7. CASE VII

The seventh case of the study was Esin. In the following, the results were presented related to (1) how her NOS understanding changed in the context of explicit reflective HOS based approach, (2) how progress trajectory in relation to integrating NOS into her lesson plans occurred as a result of feedback in the context of explicit reflective HOS based approach, and (3) which learning experiences contributed to her ability to integrate NOS into their instructional plans.

4.7.1. Change in NOS understanding

The participants' NOS views on tentative NOS, empirical NOS, inferential NOS, creative NOS, socio-cultural NOS, theory and laws well as subjective NOS were presented in that section. First, the participant's views related to tentative NOS were presented.

Tentative NOS: Before the NOS instruction Esin held inadequate views of tentative NOS. She stated that scientific knowledge (e.g. theories and laws) is absolute and does not change. Therefore, her view was categorized as inadequate. For instance, she stated that laws did not change ever, but theories could be "improved" rather than changed. This answer indicated that she perceived change of scientific knowledge as accumulation of knowledge over time but ignored the fact that change in science might occur due to changes in scientists' thinking. However, she developed her tentative NOS views and achieved informed understanding of tentative NOS at the outset of the NOS intervention. She appreciated that science could change due to the reinterpretation of current evidence or with new data. She also gave an example of Mendel law to illustrate the situation (see table73 for sample statements)

Table 73. Esin's sample statements related to tentative NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	….When I think about atom theories and evolution theory, [I can say that] theories does not change, but could be improved … … Law does not change…
Post VNOS-C	Informed	…However in science knowledge can change over time…Scientists could reinterpret the current knowledge [evidence] or could find something [new data] totally different from the current knowledge ….For example; Mendel's law is only accepted for single gene pairs. Recently chromosome theory has brought up wider explanation. Therefore, scientific knowledge may change or reinterpreted.

Participant's empirical NOS views were provided below.

Empirical NOS: Esin revealed inadequate view with regard to empirical NOS prior to the NOS intervention. She considered the purpose of experiments is to prove facts, ignored the role of evidence to support data. Moreover, she could not differentiate science form other disciplines by means of empirical basis prior to NOS intervention. Yet, at the outset of the NOS intervention, she shifted her view to adequate view of empirical NOS. That is, she brought out implications for evidence although there were not enough explanations. For instance, in her response, she stated that science involved experiments and observations but she did not explain the role of evidence or empirical basis (see table74 below for sample quotas).

Table 74. Esin's sample statements related to empirical NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	Scientists always need experiments. Experiments allow scientists to understand if their hypothesis is true or not. Scientists can only prove knowledge by experiments. In order to understand science concepts we should do experiments
Post-VNOS-C	Adequate	NOS differentiate science from other subject. Science keeps renewing itself. Science improves itself by means of observations and experiments as well as collecting data.

Following section described participant's views on inferential NOS

Inferential NOS: In pre-VNOS-C-C, Esin considered science as "what you see" and could not appreciate the role of inference in science while scientists make conclusions. That is, she implied that natural phenomena was directly accessible the human senses. For instance, in her response related to the existence of the dinosaurs she stated that fossils proved that existence of the dinosaurs which denied the role of human inference. Therefore, her view was categorized as inadequate. However, at the end of the NOS intervention, she revealed adequate view of inferential NOS. That is, her responses implied the recognition of scientists making inferences during their investigations (see table75 below for sample quotas)

Table 75. Esin's sample statements related to inferential NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	[to decide the existence of dinosaurs]They[scientists] are do research, find fossils under the stones which enable them[scientists] to prove that once dinosaurs had lived
Post-VNOS-C	Adequate	… [to decide existence of dinosaurs] They [scientists] found fossils of dinosaurs… ….we [scientists] try to find answer on what we[they] cannot observe based on our observations

Subsequent section displayed participant's views on creative NOS.

Creative NOS: At the beginning of the intervention, Esin showed adequate understanding of creative NOS. That is, she recognized the role of scientists' creativity and imagination while conducting scientific investigations. However she could not support her beliefs with example or detailed explanations. At the outset of the NOS intervention, she revealed informed understanding of creative NOS. She indicated that scientists used their imagination at all parts of the scientific investigation. Additionally, she supported her claim with a black box example which was mentioned in one of the previous science method classes (see table76 for sample quotas).

Table 76. Esin's sample statements related to Creative NOS revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Adequate	…... Let's think about the mobile phone. If scientists did not use their creativity or they did not imagine it before, the mobile phones would not like today's model. I think all technological developments include imagination and creativity of scientific people…
Post-VNOS-C	Informed	….Scientist uses their imagination and creativity in every part of investigation. For instance, in the black box experiment we saw this. You don't know what is inside, you observe and you use your imagination to figure out what is going on inside the box

Next, participant's views on socio cultural NOS were presented.

Socio Cultural NOS: Esin showed inadequate understanding of socio-cultural NOS. She stated science as universal and free from cultural norms in which science practiced at the beginning of the intervention. She shifted her understanding towards informed view at the end of the intervention. She recognized that science as a discipline which was influenced by the culture's norm and principles (see table77 for sample quotas).

Table 77. Esin's sample statements related to socio-cultural NOS revealed in pre- and post-VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	Science is universal...Science is not affected by culture, history, political values etc….
Post-VNOS-C	Informed	Scientists are human .They are influenced by their background, social, cultural beliefs etc. Scientific knowledge is subjective and socially culturally embedded. For example, if the country of scientists is suffered from flu, scientists study on this, not on the earthquake etc…

Following section described participant's view on function of theories and laws.

Theory & Law: As previous participants, Esin also held the common misconception related to the hierarchical order between theories and laws. She described theory as "proved" hypothesis and laws as the most reliable certain scientific knowledge. Therefore, her views regarding theories and laws were categorized as inadequate. At the end of the intervention, she came to recognition of laws and theories as different kind of scientific knowledge. She also was able to define theories as explanatory and laws as descriptive. Therefore, her view was categorized as informed view (see table78 below for sample quota).

Table 78. Esin's sample statements related to Theory &Law revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	Theory is the proved hypothesis…they are proved with experiments…..…Combining more than one theory is law….The order [comparing theories, laws and hypothesis] from less reliable to most reliable would be like hypothesis, theory and law. The law is more reliable than theory.
Post-VNOS-C	Informed	Theory is explanation of phenomena....Law is the generalization of natural phenomena. …There is no direct relationship between law and theory. There is no difference [regarding status of scientific knowledge]. Both of them help us to understand the nature.

Lastly, participant's views on subjective NOS were described below.

Subjective NOS: She could not recognize role of scientist' subjectivity in scientific investigations at the beginning of the NOS intervention. She held the belief that there was only one "truth" in science, and there was no place for scientists' subjectivity. For instance, in her response, she indicated the reason behind dinosaur extinction controversy due to the lack of data which denied the idea that scientists constructed their own explanations based on their theoretical frameworks, personal pre-conceptions, and assumptions. Therefore, her subjective NOS view was categorized as inadequate. Yet, she shifted her understanding towards informed view of subjective NOS at the end of the intervention. She recognized science as subjective and appreciated that scientists' background, preconceptions, experience influenced their judgments (see table79 below for sample quotas).

Table 79. Esin's sample statements related to Subjective NOS revealed in pre and post VNOS-C

Administration of VNOS-C	Categorization	Sample Statements
Pre-VNOS-C	Inadequate	[regarding existence of different theories on extinction of dinosaurs] I guess they [scientists] have not had enough data so they cannot prove why dinosaurs become extinct…They do not have enough knowledge.
Post-VNOS-C	Informed	Science is subjective .if it had not been there would no other idea about anything [Regarding existence of different theories on dinosaur extinction] Here, subjective nature of science is the issue. Scientists' preconceptions, experience, background and their creativity influence their ideas [on extinction of dinosaurs]

To sum up, participant revealed inadequate views on almost all NOS aspects at the beginning of the intervention. She shifted her NOS views towards either informed or adequate at the end of the study. She achieved informed views on tentative, creative, socio cultural, theory &law and subjective aspects of NOS, while she revealed adequate views on empirical, inferential NOS. The following section informs on firstly, Esin's progress on NOS instructional planning and secondly, the perceived sources of her development for NOS instructional planning.

4.7.2. The progress trajectory in relation to integrating NOS into lesson plans

The subsequent section presented findings related to general information related to participant's instructional planning, development of instructional planning regarding NOS objectives, development of instructional planning regarding NOS activities, development of instructional planning related to NOS assessment and general overview on participant's development related to NOS instructional planning. Next section started with general information related participant's instructional planning.

4.7.2.1. Information about instructional planning in general

Participant handed in four lesson plans and she did not turn in fourth lesson plan. She planned to teach science content such as Cell (6^{th} grade) in her first lesson plan, Solar System (grade7) in her second lesson plan, Gravitational Force (grade 7) in her third lesson plan, and Atom models (grade 8) in her last lesson plan. Similar with the other participants, she chose all the science content that she planned to teach from Turkish science curricula which was available online. It was her responsibility to choose any science content from curricula and adapt or modify it to address NOS explicitly. While creating lesson plans, she was in charge with the writing of objectives part of the lesson plan in which he stated the planned goals of her lesson, description of activities parts in which planned instructional strategies, tools were described to achieve the planned goals and lastly, evaluation part of the lesson plan, in which planned strategies were described to evaluate the planned goals. Since all participants were required to teach NOS in their lesson plans, they were expected to adapt and design lesson plans in which they address NOS explicitly. The subsequent section presented Esin's improvement regarding including NOS objectives into her instructional planning.

4.7.2.2. Development of lesson plan regarding NOS objectives

Objectives part of the lesson plans were more related with whether participants had the intention of teaching NOS explicitly/consciously. Inclusion of NOS objectives mostly indicated how they perceived teaching NOS e.g. they recognized NOS as an add-on, topic or as an important issue as the other science content to be taught/planned explicitly. Analysis of the lesson plans showed that, Esin provided NOS objectives in all last three lesson plans but not in first one. That is, her **first lesson plan** in which she planned to address cell as science content, but she did not include any objective regarding NOS. However, analysis of her lesson plan revealed her efforts to address some NOS issues such as empirical, subjective and tentative NOS. Therefore, she reminded about the function of objectives in a lesson plan by the researcher: "think about why you need to write objectives in the lesson plans….Do you think all these objectives cover your all intentions for that lesson"

In her second, third and fifth lesson plans she gave place NOS objectives in objectives part of lesson plan. For instance in her **second lesson plan,** in which solar system was covered**,** she stated general NOS objective covering aspects such as subjective, tentative and empirical NOS. The objectives she wrote were as followings: "Realize the science is a tentative process" and "Understand the nature of science (Subjectivity, tentativeness, empirical based)". In her third lesson plan she planned to teach force and motion and she planned to teach atom models in her fifth lesson plan. For the **third and fifth lesson plans**, she kept her manner and included more general NOS objective as in her previous lesson plan. The objectives were as "Understand the aspects of nature of science (subjectivity, tentativeness)" and "Recall the nature of science aspects; creativity, tentativeness, empirically based, and subjectivity."

Overall, the examination of her lesson plans revealed that she adopted the idea of addressing NOS in objectives parts of the lesson plans. She did not provide any NOS objective in her first lesson plan, but she started to include NOS in objectives part for the rest of the lesson plans. Although she did not write separate objectives for each NOS aspect she wanted to emphasize, she mostly stated tentative NOS in her lesson plans. The following table showed the objectives that Esin stated in each lesson plan.

Table 80. NOS objectives in each lesson plan

# of lesson plans	Grade level	Science content	NOS aspects	NOS objective
1	6^{th}	Force and Motion	-	-
2	7^{th}	Solar system	Empirical NOS	Understand the nature of science (Subjectivity, tentativeness, empirical based).
			Subjective NOS	Understand the nature of science (Subjectivity, tentativeness, empirical based).
			Tentative NOS	Realize the science is a tentative process Understand the nature of science (Subjectivity, tentativeness, empirical based).
3	7^{th}	Force and Motion	Tentative NOS	Understand the aspects of nature of science (subjectivity, tentativeness)
			Subjective NOS	Understand the aspects of nature of science (subjectivity, tentativeness)
4	NA	NA	NA	NA
5	8^{th}	Atom models	Empirical NOS & Subjective NOS & Creative NOS & Tentative NOS	Recall the Nature of Science aspects; “creativity, tentativeness, empirically based, and subjectivity

-: indicated the absence of the subject, NA: not applicable

Post interview conducted to understand her perceptions on NOS instructional planning regarding to her perceived development of NOS lesson planning, rationale for teaching NOS at the end of the study. Additionally, she was asked to write a reflection paper on her NOS teaching perception at the end of the study. Related to writing NOS objectives, post interview also supported her manner of including NOS objectives. She stated that she started to provide NOS objectives towards last lesson plans in response to interview:

E: I did not think of writing NOS objectives at first. Then towards my last lesson plans I started to write NOS objectives.

The following section described the development of participants' explicit-reflective NOS instructional planning through the activities part of the lesson plan.

4.7.2.3. Development of lesson plans regarding NOS activities

This section informed about in what ways and to what extent the participant achieved to adopt explicit-reflective approach to teach NOS. In her **first lesson plan**, in which she planned to teach cell, and showed efforts NOS teaching efforts in her plan by including subjective and empirical NOS. In her instructional plan, she wanted students to examine onion skin and blood sample under microscope to note down the differences between two different cell types:

"…The classroom will be divided into two groups. One group will be given onion skin, and the other one will be given blood drop .Teacher wants them to observe plant cell and animal cell by group under microscope. Each group will observe the sample which they are responsible, and they will try to draw what they observe. After this activity, the groups will exchange their samples to observe the other cell type. After completing this activity, teacher wants students' to present their drawings."

After that, she provided some questions to address subjective and empirical NOS. Then she directly gave definitions of each aspect. For instance, regarding subjective NOS, she asked a question related to activity and then she explained subjective NOS and empirical NOS:

"What are the differences and similarities between your drawings? When they complete their discussion, teacher explains why they draw differently from each other. Subjectivity [she explains each NOS aspect]: Science is subjective, scientist states different hypothesis even if they look at the same data. Similarly, you did the same thing, you look the same cells with same microscopes but you draw different from each other. You cannot be objective while you study scientific issues. Empirical based; what you draw your paper is based on your observations and experiments. While you are stating a hypothesis, you should base your results to your observations and experiments in a logical way. In here you did an experiment related to it, you draw your cells by looking through the microscope. Then teacher gives the differences and similarities between plant and animal cells and shows the pictures of the two cells…”

She displayed some confusion related to subjective NOS. She did not show the perspective of subjectivity of scientist while making inferences or proposing conclusions. Additionally, she failed to connect microscope activity with NOS, instead she directly give definitions of NOS terms. Thus, she got alerted on connectıng the ınstructional prompt with NOS. For that reason, her instructional plan regarding empirical and tentative NOS was categorized as *needs development.*

In second lesson plan, she planned to teach tentative, empirical and subjective NOS in the context of solar system. Unlike her previous lesson plan she also covered these NOS issues in objectives part of the lesson plan. Similar with the previous lesson plan, she provided students with HOS based script which was related to two different theories proposed in past about solar system. She provided two kinds of models; geocentric model and heliocentric model:

“Geocentric model: …… is the theory that the Earth is the center of the universe and other objects go around it. …..It was embraced by both Aristotle and Ptolemy, and most, but Heliocentric model**:**…., is the theory that the Sun is stationary and at the center of the universe. Historically, heliocentric model was opposed to geocentrism, which placed the Earth at the center. Discussions on the possibility of heliocentrism dated to classical antiquity. It was not until the 16th century that a fully predictive mathematical model of a heliocentric system was presented, by mathematician and astronomer Nicolas Copernicus...”

Then she also provided some NOS questions to initiate NOS discussion:

“The teacher asks students “What caused this [regarding geocentric model] knowledge has been changing of? “Why the first knowledge [regarding geocentric model] has been changed? “What do you think about this, do you know any idea?” The teacher helps students to understand the basic elements of NOS which are “empirical based, tentativeness, subjectivity”, but she does not give the answers directly, just helps students to realize this knowledge ….”

Although it was obvious that she had intention to emphasize NOS, she could not connect the content or the example with NOS and she could not keep up and conclude questions she provided. It was not clear that how she would connect e.g. change in knowledge on solar system would be connected with empirical NOS. That is she failed to connect HOS example with NOS properly. Therefore, instructor warned her to have more specific/concrete NOS questions such that: “you should also indicate that which question is for which NOS aspect e.g. Which aspect do you intent to teach while you are asking What caused this knowledge has been changed”

In general, although she addressed the NOS aspects that she also stated in objectives part of the lesson plan, she needed to be more reflective regarding her NOS instruction. Therefore her instruction related to empirical and tentative and subjective NOS categorized as “needs development”.

In her **third lesson plan**, she planned to teach force and motion as science content. She stated subjective and tentative NOS in objectives and description of activities parts of the lesson. In her plan, she started her lesson with hands on activity asking students to explore free fall of two different kinds of objects by using “*predict-observe-explain*” strategy:

“…The teacher starts lesson with an activity: …Give them paper and coin and ask “Which one reaches the bottom first?” Therefore, they [students] make prediction….” Then she wanted students to make an experiment about fall of two identical papers with two different shapes. Then she wanted students to note down their predictions and observations: “…….. Teacher wants students to write step by step what they did and what they observe. After this activity teacher gives students two identical papers. One of them is ruffled, the other is not. And teacher wants the students to do the same procedure again as they do in Activity 1. Also ask them whether their prediction is same with their observation. Why/or why not? After a class discussion teacher continues her lesson…”

After, she continued giving brief information on how Galileo made contribution on knowledge of falling objects:

“…We know that the objects are allowed to release from top, they fall down to the bottom. We conclude this from our observations. The falling objects have always attracted the scientists’ interests, and it is the subject to research. In this area, the best-known study is said Galileo Galilee. Before the Galileo, there was a misconception about the falling objects. The people had thought the heavy objects reached the bottom first. However, Galileo throw two different objects from the top of the Pisa Tower. After Galileo observed the objects which were released from the top, even if they were not reach the bottom at the same time, but they reached bottom in a closer time…"

Although she provided some hands on activity for teaching concept of free fall, she directly planned to teach NOS aspects through lecturing right after she gave HOS example:

"…Subjectivity: The people thought the heavy object would reach the bottom first but Galileo did not think like that. He thought that getting the floor does not depend on weight.

Tentativeness: Believing the weight affects reaching the time to the bottom of the objects; however this knowledge has changed after Galileo…."

Here, she was reminded about her manner of teaching NOS which was direct teaching. Thus, the researcher suggested her to lead students to make these conclusions regarding NOS, rather than giving direct definitions of NOS aspects: "You are expected to make students come that conclusion rather than making direct teaching…" In addition to the tendency of her direct NOS teaching, she did not state clearly how the given examples reflected these NOS aspects. Therefore, she warned on to be clear on how these examples help students to understand these NOS concepts. In sum, despite of the some drawbacks, she included NOS objectives and made efforts to include some instructional prompts to address these NOS aspects. However, she could not add proper NOS questions, or connect the examples with NOS either. Therefore, her lesson plan efforts regarding subjective and tentative NOS was categorized as "needs development".

In the **fifth lesson plan,** she planned to teach atom models and also she planned to cover subjective, tentative, creative and empirical NOS in which she also stated in objectives parts. She adopted a lecturing approach through all over the lesson plan. She first gave information on four types of atom models, and then she pointed out NOS aspects:

"…During the introduction of the lesson, the teacher will explain to students that models are important to scientists because models help them make predictions. For example, scientists can use the model of an atom to predict how a particular substance will act when it is combined with other substances. When new evidences are found, or the new experiments are designed the models have changed with time. This helps us to understand the tentativeness and the empirical based aspects of Nature of Science. And the every model reflects each scientist's different creativity. The models change from scientist to scientist. Subjectivity also related with creativity…"

Similar to her previous lesson plans, her lesson plan was lacking of reflective component. That is, she did not included NOS questions to initiate NOS discussion and encourage students reflected on their NOS views. However, she included objective related to these NOS aspects. Therefore, her lesson plan was categorized as *need development.*

Overall, examination of lesson plans revealed that she improved her instructional planning towards more explicit reflective way of teaching NOS. She mostly used HOS examples and lecturing in her plans to address NOS. Although she was lack of providing instructional prompts to emphasis NOS, at least she achieved to shift her lesson plans being implicit to somehow "needs development" level of explicit reflective instructional planning regarding NOS. The most used aspects were subjective NOS followed by tentative and empirical NOS. Interview and reflection paper which were gathered at the end of NOS intervention were used as additional data source. In interview, participant responded questions related to her NOS teaching perception and her instructional planning development. She also asked to write reflection paper on her NOS teaching perception. Analysis of responses to interviews and reflection paper supported her manner of NOS teaching approach in her lesson plans. She stated that she would teach NOS as an embedded to science content and by using HOS examples in her responses to interview:

R: How would you teach NOS to the students, in what ways?

E: …It could be integrated into the content. You can provided some HOS examples and also could teach the science content…you can connect to NOS as well. Students might not understand [NOS], thus better to guide them. I guess, NOS could be taught by connecting the students' activities with how scientist works through discussion.

Moreover, she emphasized NOS instruction to be explicit in her reflection paper:

"I think I should teach NOS via the explicit instruction. We did some activities in order to understand the aspects of NOS in our lecture hours, I think they are helpful for teaching this aspects. I may design some activities; I plan to teach the NOS as possible as the enjoyable way."

Additionally, she was aware of her development regarding NOS lesson planning. She stated that she started to mention NOS towards her last lesson plans in her interview:

R: How do you think your NOS integration into description of activities part of the lesson plan?

E: I taught NOS through discussion [in lesson plans]. In my first lesson plans I did not address NOS. But towards last lesson plans, I started to emphasize how science advanced, how scientists could think and work differently.

Following table indicated each NOS aspect she planned to teach in *activities part,* and the instructional strategies she planned to use to teach NOS:

Table 81. Summary of NOS aspects addressed in description of activities part of lesson plan

# of lesson plan	Grade level	Science content	NOS aspects	NOS teaching strategies	Explicit-Reflective
1	6^{th}	Force and motion	Tentative NOS	HOS example	Needs development
			Empirical NOS	HOS example	Needs development
2	7^{th}	Solar system	Subjective NOS	HOS example	Needs development
			Tentative NOS	HOS example	Needs development
			Empirical NOS	HOS example	Needs development
3	7^{th}	Force and Motion	Tentative NOS	Lecturing	Needs development
			Subjective NOS	Lecturing	Needs development
4	NA	NA	NA	NA	NA
5	8^{th}	Atom Models	Empirical NOS	Lecturing	Needs development
			Creative NOS	Lecturing	Needs development
			Subjective NOS	Lecturing	Needs development
			Tentative NOS	Lecturing	Needs development

✓ : indicated the existence of the task, - : indicated the lack of task, NA: not applicable

Next, participant's development in NOS assessment revealed through lesson plan analysis was presented.

4.7.2.4. Development of lesson plans regarding NOS assessment

This section informed about the kind of assessment strategies Esin used while assessing NOS aspects in her lesson plans. Examination of Esin's lesson plans revealed that she did not assess students' NOS understanding despite of the feedback she got related the assessment of NOS.

Through the responses to post-interview which was conducted to explore her perceptions on NOS instructional planning, she explicated her inability to asses NOS in her lesson plans. Although she mentioned the necessity of addressing NOS in evaluation part of the lesson plans, she could not able to write any NOS questions. She wrote questions only related to science content:

E: I did not NOS assessment in my lesson plans….Actually, I knew that I needed to assess NOS understanding. But I did not know how to write questions targeting to asses NOS…

Following section outlined overview of the participant's development regarding NOS instructional planning.

Subsequent section presented an overview of the Esin's development regarding NOS instructional planning.

4.7.2.5. General overview for NOS instructional planning

In general, she improved her instructional planning related to NOS through lesson planning. Regarding NOS objectives, although she did not state any NOS objective at her first lesson plan, she included NOS objectives in the rest of lesson plans. Concerning description of activities parts of lesson plans, she revealed some efforts to address NOS. She mostly used lecturing and HOS examples to emphasize NOS. Despite of her efforts to address NOS within an explicit reflective approach, she failed to include NOS questions to initiate NOS discussions or connect HOS examples to NOS to create opportunities for students rethink and revise their NOS views. She could not achieved "*exemplary*" form of explicit reflective NOS instructional planning for any NOS aspects. She mostly addressed tentative, empirical and subjective NOS in her plans as "*needs development*" form of NOS instruction. Yet, she achieved informed view on tentative and subjective NOS, adequate view on empirical NOS. However, she was consistent in her lesson plans regarding objectives and description of activities parts. That is, she addressed NOS aspects in both objectives and description of activities parts as well. However, she did not consider NOS evaluation in her lesson plans.

General overview of Esin's instructional planning regarding objectives, description of activities and evaluation parts of the lesson plans was summarized in the following table:

Table 82. Summary of overall NOS instructional planning

# of lesson plan	Grade level	Science content	NOS aspects	NOS teaching strategies	Explicit-Reflective	NOS objectives	NOS evaluation
1	6th	Force and motion	Tentative NOS	HOS example	Needs development	-	-
			Empirical NOS	HOS example	Needs development	-	-
2	7th	Solar system	Subjective NOS	HOS example	Needs development	✓	-
			Tentative NOS	HOS example	Needs development	✓	-
			Empirical NOS	HOS example	Needs development	✓	-
3	7th	Force and motion	Tentative NOS	Lecturing	Needs development	✓	-
			Subjective NOS	Lecturing	Needs development	✓	-
4	NA	NA	NA	NA	NA	NA	NA
5	8th	Atom Models	Empirical NOS	Lecturing	Needs development	✓	-
			Creative NOS	Lecturing	Needs development	✓	-
			Subjective NOS	Lecturing	Needs development	✓	-
			Tentative NOS	Lecturing	Needs development	✓	-

√ :indicated the existence of the task, - : indicated the lack of task, NA: not applicable

Following section will inform on participant's perceived source of development for NOS instructional planning.

4.7.3. Learning experiences contributing to the ability to integrate NOS into instructional plans

In general, Esin's instructional planning for teaching NOS has been evolved in an explicit reflective manner which included NOS objectives, specific activities for teaching NOS. The researcher used several strategies to improve participants' NOS instructional such as feedback to lesson plans, HOS based examples coupled with NOS explicitly followed by NOS discussions, and lesson plan presentations followed by NOS discussions as well. To understand the relative importance of these learning experiences, researcher conducted interview with participants. Analysis of interview revealed that Esin perceived peer presentations and follow up discussions after peer presentations as the main source contributing to her ability to integrate NOS into instructional plans:

R: As a researcher, I aimed to help you improve your NOS understanding and NOS instructional planning. For this reason, I applied several strategies such as giving feedback for lesson plans, providing HOS examples in class and asking you to prepare and present lesson plans, which was followed by class discussions. Which of these activities do you think influence your skills regarding NOS instructional planning?

E: We were discussing the lesson plan presentations regarding how better we could integrate NOS. I guess we better understand NOS and NOS integration through the discussions. Because of that, it [discussions] made a good contribution to my development regarding NOS instructional planning.

4.8. General overview

4.8.1. Summary of participants NOS understanding

In sum, participants revealed a substantial improvement in their NOS views. None of the participant held inadequate view of any NOS aspect at the end of the science methods course. More dramatic change occurred regarding the understanding of the role and function of theories and laws and socio-cultural NOS aspects. All participants held misconception related to hierarchical order between theories and laws, and "universal" science. At the end, all of the participants achieved improved understanding the functions of theories and laws and socio-cultural NOS. Similarly, six of the participants held inadequate understanding of subjective and tentative NOS at the beginning of the science method course. All of the participants improved their views as informed understanding of tentative and subjective NOS at the end of the science methods course. Total of the five participants held inadequate views of empirical NOS prior to NOS intervention. At the end of the NOS intervention, five of the participants developed their views such that all of them displayed informed understanding of empirical NOS. Two of the participants who held inadequate understanding of empirical NOS initially, developed their understanding towards adequate empirical NOS view as well. Regarding creative NOS, three participants held adequate understanding and four participants had inadequate understanding of creative NOS. All participants shifted their creative NOS understandings towards informed view at the end of the intervention. Surprisingly, almost half of the participants indicated adequate understanding of inferential NOS at the beginning of the NOS intervention. At the end of the NOS intervention, six of the participants achieved informed understanding of inferential NOS, whereas only one participant holding inadequate view of inferential NOS achieved adequate inferential NOS view. To sum up, all participants achieved mostly informed views of NOS for various aspects at the end of the science methods course. None of the participants revealed inadequate understanding for any NOS issues at the end of the NOS intervention. Following table 83 indicated participants' pre and post NOS views with regard to each aspect over the science methods course:

Table 83. Participants' pre and post NOS views over NOS intervention

	Tentative NOS		**Empirical NOS**		**Inferential NOS**		**Creative NOS**		**Social-cultural NOS**		**Theory& Law**		**Subjective NOS**	
Participants	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre
Safa	I	IA	I	A	I	A	I	IA	I	IA	I	IA	I	IA
Lale	I	IA	I	IA	I	A	I	IA	I	IA	I	IA	I	IA
Lia	I	A	I	A	I	A	I	A	I	IA	I	IA	I	NC
Simge	I	AI	I	IA	I	A	I	IA	I	IA	I	IA	I	IA
Ebru	I	IA	A	IA	I	IA	I	IA	I	IA	I	IA	I	IA
Melis	I	IA	I	IA	I	IA	I	A	I	IA	I	IA	I	IA
Esin	I	IA	A	IA	A	IA	I	A	I	IA	I	IA	I	IA

IA: Inadequate; A: Adequate; I: Informed; NC: Non categorize

4.8.2. Summary of participants NOS instructional planning

Generally, all participants developed their instructional planning for teaching NOS. At the end most of them provide NOS objectives, explicit reflective NOS instructional planning and some assessment strategies specific to NOS. All of the participants achieved explicit and reflective planning of at least one aspect except one participant. Among the explicit reflective NOS instructional planning, empirical NOS was the most achieved one in lesson plans done by six participants. It was followed by tentative NOS and achieved by five participants and subjective NOS achieved by four participants explicitly and reflectively in lesson plans. Following figure 2 summarizes the NOS aspects that were truly planned as explicitly and reflectively in lesson plans:

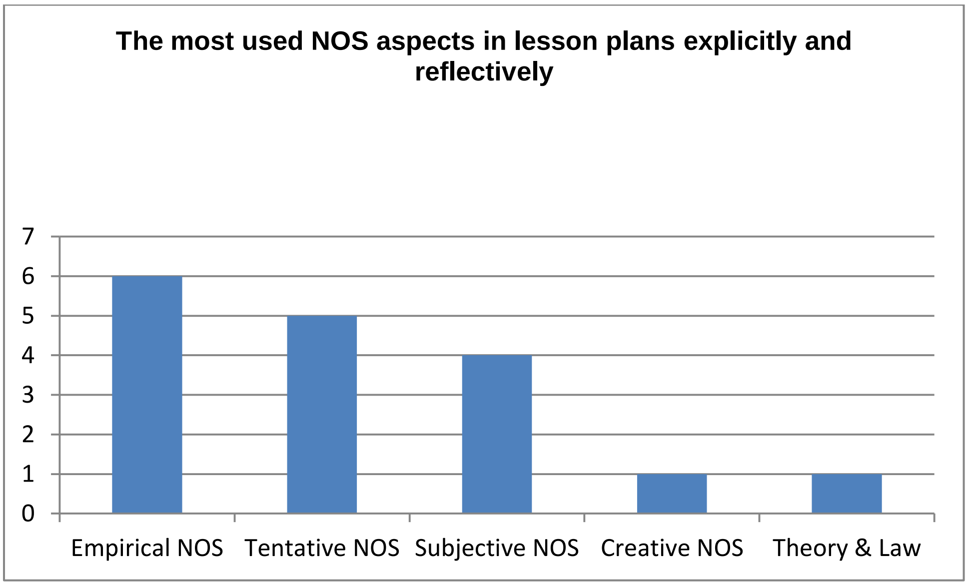

Figure 2. The most used NOS aspects in lesson plans explicitly and reflectively

Regarding evaluating students' NOS understanding in lesson plans participants mostly considered NOS assessment in evaluation part of the lesson plans towards the last lesson plans. Two participants did not think of including NOS in evaluation part in any of lesson plans. The other participants mostly used chart creation, concept map, homework, reflection paper and NOS questions. Following figure 3 showed the assessment strategies used by the participants in lesson plans:

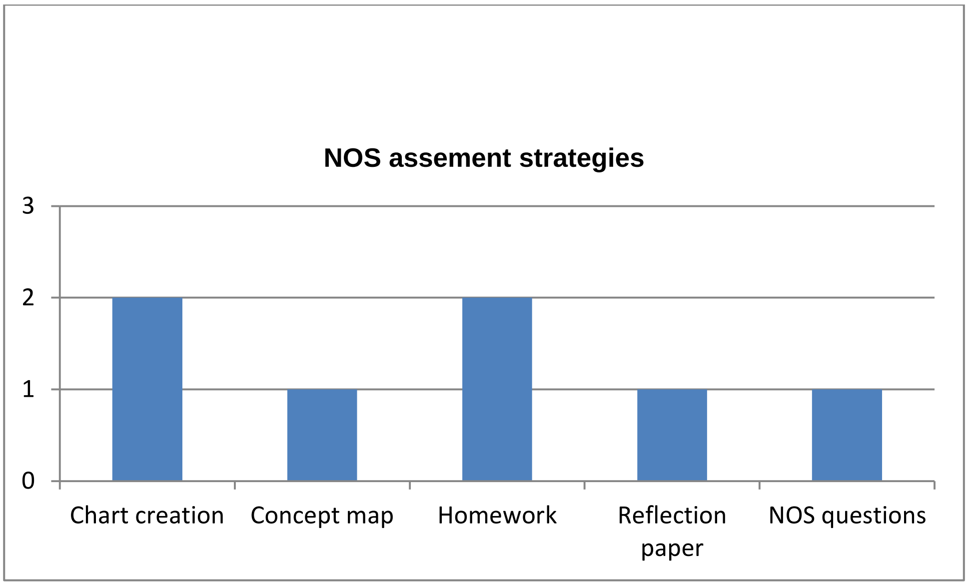

Figure 3. NOS assessment strategies

Additionally, participants showed consistency for some NOS aspects among the parts of lesson plan (e.g. objectives, description of activities and evaluation parts). It was empirical and tentative NOS aspects that they revealed more consistency among others. Following figure 4 illustrated the NOS aspects that they addressed in three parts of the lesson plan:

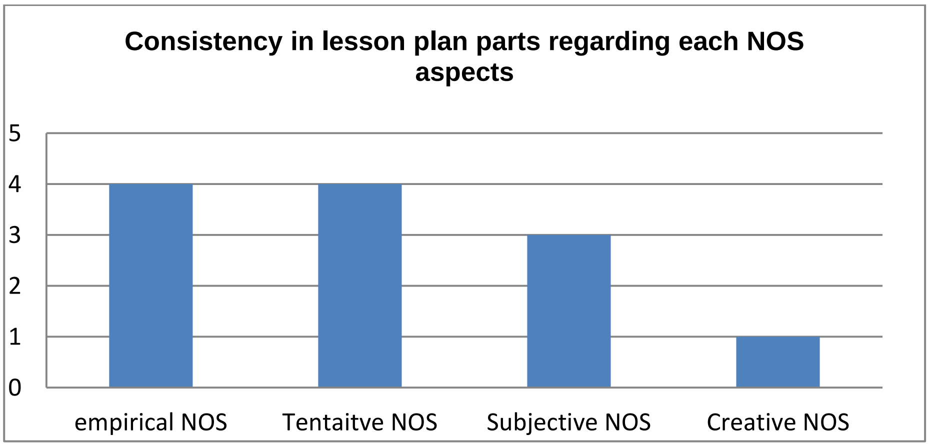

Figure 4. Consistency between lesson plan parts regarding NOS aspects emphasized

Regarding the science content they chose, mostly atom models and inheritance & cell, and solar system. Following table illustrated the science content chosen by participants:

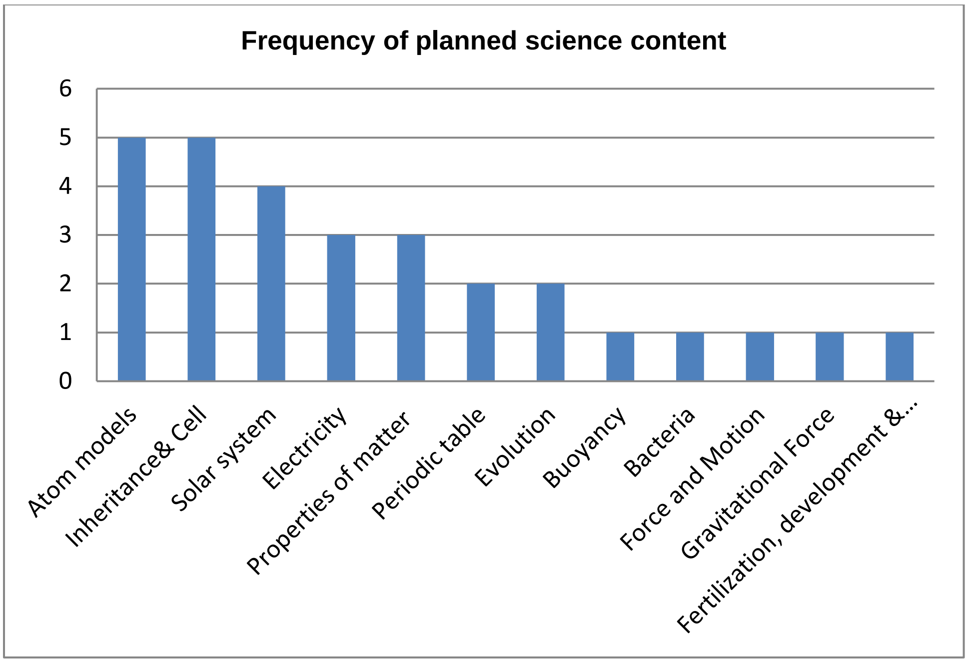

Figure 5. Science content to be chosen in lesson plans

Moreover, participants were attributed to their development for instructional planning NOS to several sources provided through the course. Mostly they perceived lesson plan presentations followed by discussions as main source contributing their NOS instructional planning. Additionally, they stated the importance of feedback given to their lesson plans, lesson plan creation and HOS examples provided within course. Following figure 6. illustrated the perceived source of participants' development of NOS instructional planning:

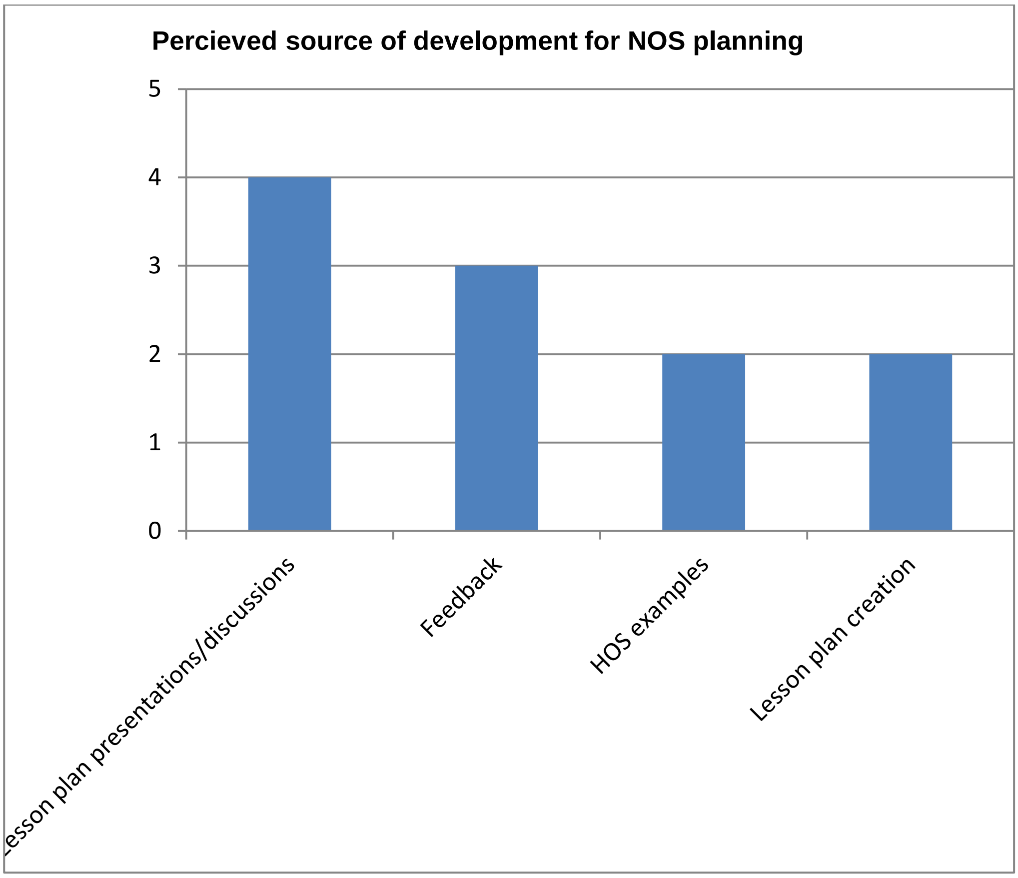

Figure 6. Perceived source of development for NOS planning

CHAPTER 5

DISCUSSION, CONLUSION and IMPLICATIONS

This chapter presented the discussion of the findings in terms of change in pre-service science teachers NOS views, their development of NOS instructional planning and the learning experiences contributed to their NOS instructional planning. Then, conclusions were made based on the findings of the study. Lastly, implications for science teacher educators, teachers, and curriculum developers were presented.

5.1. Discussion

In this part, findings were discussed related to how and to what extent the pre-service science teachers' NOS views changed and how the explicit reflective contextualized NOS instruction contributed to this change in pre-service science teachers' NOS understanding and NOS instructional planning.

5.1.1. Discussion of the findings for change in participants' NOS understanding

First, in present study, the vast majority of the pre-service science teachers held inadequate views particularly on the functions of theories and laws, socio-cultural embeddness of scientific information, role of scientists' subjectivity in development of scientific knowledge, tentative nature of scientific knowledge and empirical nature of scientific knowledge. That is, pre-service science teachers believed that science is objective, scientific knowledge is absolute and only theories could change while laws do not. This finding is consistent with the literature concluded that both pre-service and in-service science teachers had naïve NOS understanding (Abd-El-Khalick & Lederman, 2000; Abd-El-Khalick & Akerson, 2004; Akerson & Donelly, 2008; Bell, Matkins, & Gansneder, 2011; Demirdogen, 2012; Haidar, 1999; Kaya, 2012; Tairab, 2001; Liu & Lederman, 2007; Shim, Young, & Paolucci, 2010; Tasar, 2006; Ozgelen, Tuzun, & Hanuscin, 2012; Yalvac, Tekkaya, Cakiroglu, & Kahyaoglu, 2007). Vast majority of the empirical studies reported both pre-service and in-service science teachers' inadequate views particularly on the functions of theories and laws, subjective, socio-cultural, tentative and empirical NOS (Abd-El-Khalick & Lederman, 2000; Aslan, 2009; Dogan & Abd-El-Khalick, 2008; Schwartz, Lederman, & Crawford, 2004; Yalvac et.al. 2007). The pre-service science teachers' inadequate views realized at the beginning of the present study might have resulted from their experiences they gained through their primary, secondary and college education. During their education at all levels, NOS has been miscommunicated implicitly. In other words, teachers' language, structure of laboratory activities and science textbooks contributed to the development of naïve NOS views. For instance, Clough (2006) stated that very few teachers conveyed NOS accurately in classes although major reform documents highlighted the importance of accurate NOS communication to the students. Teachers who reflected their positivist science views in class or who just misused some word which were important in science settings (e.g. use word of theory for uncertain, tentative things) were the some significant reasons for students' naïve NOS ideas. Structure of science laboratory activities might have lead built of inaccurate NOS views for students. Starting from primary level to college level, laboratory activities followed step-by-step procedure, asking only report of end product and lacking of focus on how scientific knowledge was constructed. That kind of tasks conveyed science as procedural and objective activity seeking only one correct answer. In addition to these, science textbooks treatment of science portrayed inadequate science views (Abd-El-Khalick, Waters & Le, 2008; Bell, 2004; Clough, 2006; Irez, 2009; Vesterinen, Aksela, & Lavonen, 2011). For instance, Irez (2009) assessed secondary school biology textbook regarding the depiction of nature of science. He reported several problems related with the way nature of science portrayed. The analysis of textbooks indicated that science was presented as collection of facts, and procedural activity. Additionally, the author pointed out that aspects of science were neglected in biology textbooks, Similarly, Abd-El-Khalick, Waters and Lee (2008) and Niaz and Maza (2011) investigated NOS in secondary school chemistry textbooks. They reported the inaccurate NOS dimensions reflected in textbooks. For example, they outscored the so-called hierarchical relationship between theories and laws. In sum, teachers' language during instruction, science textbooks and science laboratory activities might have been the settings that students built their inaccurate NOS conceptions.

However, findings of the study revealed substantial improvements in pre-service science teachers' NOS views regarding creative, inferential, socio-cultural, empirical, subjective NOS as well as function and definition of theories and laws in this study at the end of the contextualized explicit reflective NOS intervention. Majority of pre-service science teachers shifted their inadequate NOS views towards informed views as a result of the contextualized explicit reflective NOS intervention. These positive results of the study in relation to developing favourable NOS conceptions have showed effectiveness of the contextualized explicit reflective NOS instruction as indicated previous studies (Abd-El-Khalick, & Akerson, 2009; Akerson, & Donelly, 2008; Bell, Matkins, & Gansneder, 2011). The substantial contribution of the explicit reflective NOS instruction to the development of pre-service science teachers' NOS views was attributed to the setting of the explicit –reflective NOS instruction in the present study which integrated range of decontextualized and contextualized explicit reflective NOS activities as suggested by Clough (2006).The current study embodied decontextualized NOS activities first, which enable pre-service science teachers to understand their initial NOS concepts, revise their concepts, and reflect on their relative status of these concepts without pressure of understanding of science concepts (Abd-El-Khalick& Akerson, 2004). Since decontextualized NOS activities were found to be limited to gain deeper NOS understanding (Abd-El-Khalick, 2001), explicit reflective NOS instruction continued with various contextualized opportunities for pre-service science teachers to develop meaningful NOS understanding. HOS has been chosen to provide contextualized opportunities for pre-service science teachers in the present study. For instance, pre-service science teachers were provided with examples from HOS highlighting all the relevant NOS aspects. They were encouraged to think how these examples from HOS reflected specific NOS aspects. Throughout these examples, they also had a chance to revise their NOS conceptions through various settings such as life of scientists, and important scientific discoveries within HOS. In parallel, HOS was claimed to serve as an effective way to contextualize NOS instruction because historical examples related to science aided as specific reference to NOS tenets by some researchers.(Abd-El-Khalick, 2001; Abd-El-Khalick & Lederman, 2000; Clough, 2006; Howe & Rudge 2005; Paraskevopolou & Koliopoulos, 2011). It was also claimed that HOS provided learners with opportunities not only to learn issues relating to NOS but also science content (Clough, 2006; Howe & Rudge 2005; Paraskevopolou & Koliopoulos, 2011).

In addition to HOS context, the current study also provided science content as a context to revise and refine NOS ideas. By means of science content, the pre-service science teachers were involved in specific pedagogical practices such as planning, presenting and discussing NOS lessons which were supposed to prepare as integrated to K-12 science content explicitly and reflectively.These specific pedagogical practices provided pre-service science teachers with structured opportunities to reflect on their NOS conceptions and also assess their NOS conceptions in the context of science content. For example, while designing NOS lessons, pre-service teachers needed to revise their NOS conceptions to be able to integrate these concepts into their lesson plans within science content from elementary science curriculum. For instance, participants were expected to design a lesson e.g. for atom models and integrate NOS explicitly and reflectively at the same time. To be able to do so properly, participants needed to comprehend NOS in the context of atom models and embedded NOS accurately. This process required pre-service science teachers to scrutinize their NOS concepts in-dept. Furthermore, presentation of lesson plans followed by class discussions helped pre-service science teachers revisit their NOS concepts which resulted in deeper understanding of those NOS aspects. In sum, this content- rich context embodied science content and HOS contributed to the effectiveness of explicit-reflective NOS instruction, which resulted in informed views of pre-service science teachers as suggested by other researchers (Abd-El-Khalick, & Lederman, 2000; Abd-El-Khalick, 2001; Abd-El-Khalick, & Akerson, 2004; Clough, 2006; Deniz, 2007; Schwartz, & Crawford, 2004). In the present study, almost half of the pre-service science teachers showed adequate understanding of inferential NOS even at the outset of the study. That is, four out of seven pre-service teachers inferred that all scientific knowledge is not accessible to senses and scientists might have clues about some scientific knowledge which they made conclusions based on it. However, these pre-service teachers failed to emphasize that scientists make inferences based on data explicitly. In addition, they could not provide extended explanation about their understanding on inferential NOS. These four pre-service science teachers' adequate views might be related to the context familiarity of the VNOS questionnaire question related to the views on inferential NOS. In the VNOS questionnaire, the inferential NOS views of the participants were assessed based upon the responses related to the extinction of dinosaurs. Debates of extinction of dinosaurs were issued mostly on media through popular science magazines and popular movies related to the dinosaurs. Supporting this notion, Nisbet et al. (2002) stated that media had a significant role in promoting public's perception of science and scientists. For instance, in media scientists' job was depicted as to solve and explain the mysterious of the world. Therefore, pre-service science teachers' personal experiences with these informal leaning opportunities such as media, magazines and movies have conveyed more appropriate messages related to inferential NOS. In other words, their prior conceptions related to inferential NOS might be built in these informal learning experiences and variety of personal experiences. This explanation was also consistent with Hogan(2000)'s claim related to construction of NOS views which stated that students made generalizations on notions about nature of science based on their personal experiences with science

5.1.2. Discussion for the development of NOS instructional planning

In this section, I discussed the pre-service science teachers' evolution of translation of NOS views into instructional planning. The discussion related to the development of NOS lesson plans, particularly considering the participants' development in writing NOS objectives, providing NOS instructional strategies and NOS evaluation, is provided. Finally, discussion on the relationship between NOS understanding and translation of these understanding into lesson plans was presented.

Analysis of lesson plans revealed that all participants showed substantial development in their NOS integrated lesson plans. Through the intervention, each participant prepared five lesson plans aimed to teach different science content and NOS aspects. Participants were supported while preparing lesson plans through feedback by the researcher, one to one correspondence if needed, and discussions. Scrutinizing participants' development of NOS instructional planning closely, each part of the lesson plans (e.g. objectives, activities, and evaluation parts) indicated substantial improvement related to NOS integration at varying degrees.

Regarding NOS objectives, majority of the participants did not consider including any NOS objectives in their lesson plans at first; although, they attempted to include NOS in their lesson plans through some instructional prompts. After the second lesson plan, NOS objectives have been seen in the lesson plans. Some participants wrote too general NOS objectives such as "students understand NOS", but through fourth and fifth lesson plans more NOS objectives specifically targeting each NOS aspect such as "students will realize that science is tentative" were written. In responses to interviews, the pre-service teachers mostly stated that they did not think of the inclusion of NOS in the objectives part of the lesson plans at first. The possible reason for not including NOS objectives might be related to pre-service science teachers' intentions on planning the lesson and how they value NOS. That is, initially, pre-service science teachers did not aimed to teach NOS as other science content in their lesson plans. Also, they did not value NOS as much as they value other science content. Likewise, previous studies pointed out that teachers' goals and intention influence their choice to implement NOS into instruction. Therefore, they need to view NOS as valuable instructional outcome as other science content first to consider implementing NOS in their instructional practices (Bell, Lederman, & Abd-El-Khalick, 2000; Lederman, 1999; Schwartz & Lederman, 2002). Therefore, for the current study, it can be concluded that the inclusion of NOS objectives especially for the ones particularly targeting specific NOS aspects indicated that participants started to value NOS as an important content to teach as other science content and perceived NOS as a cognitive outcome. Additionally, it also indicated that pre-service teachers think NOS as an integral part of their science instruction rather than an add-on part to their teaching. That is, they perceived NOS as kind of science content (e.g. like atom models) to be taught rather than perceiving NOS as an extra-curricular activity. In that sense, the notion of NOS as an instructional outcome was one crucial factor influencing development of PCK for NOS (Abd-El-Khalick, Bell, & Lederman, 1998; Bell, Lederman, & Abd-El-Khalick, 2000; Schwartz, & Lederman, 2002). In the current study, lesson plan preparation and feedback might have contributed to the development of notion of NOS as an instructional outcome. Through lesson planning, each participant was encouraged to think about the function of objectives and why they need to write NOS objectives through feedback to lesson plans. Accordingly, it might be concluded that lesson planning served as an important task to practice NOS objective writing and feedback helped to gain meaningful development for PCK for NOS (Abd-El-Khalick, 2005; Gess-Newsome, 1999).

Related to NOS instructional strategies, majority of the participants either planned to teach NOS in an implicit way or in a didactic way (e.g. lecturing) for the first two lesson plans. That is, participants could not transfer their NOS understanding into different other contents in an explicit reflective way even they held informed views of NOS. This result confirmed the fact that having desired NOS understanding does not enable them to transfer their understanding into instructional practices effectively (Abd-El-Khalick, & Lederman, 2000; Lederman, 1992, 1999). One of the possible reasons for the lack of translation of NOS views into instructional plans for the first two lesson plans might be the lack of their PCK for NOS. PCK for NOS was reported to be one of the crucial factors impeding pre-service science teachers to transfer NOS into their instructional practices effectively (Clough, 2006; Hanuscin & Hian, 2009; Lederman, 2007).

However, towards last lesson plans nearly all participants planned explicit reflective teaching of NOS in their lesson plans. Specifically for the fourth and fifth lesson plans, majority of the participants could situate NOS into lesson seamlessly. They used discussion, questioning, and HOS examples to address NOS. It seemed that they developed skills to well connect NOS to science content through hands on activities, discussion, questioning strategies and examples from HOS. It could be concluded that they gained skills to make instructional strategies specific to NOS. This result showed that participants developed knowledge of instructional strategies to address NOS which showed the development of some level of PCK for teaching NOS (Akerson & Hanuscin, 2007; Demirdogen, 2012; Wahbeh, 2009). The success of translation of NOS views into instructional plans through various strategies underscored the contextual nature of NOS learning (Abd-El-Khalick, 2001). That is, the strategies that pre-service used to address NOS was mostly provided through the contextualized intervention implemented in the study. For instance, content generic activities were used to get attention of pre-service science teachers to NOS concepts. Additionally, HOS examples were used to help pre-service teachers to deepen their NOS conceptions and provided a context for discussion of NOS ideas (Clough, 2006; Dass, 2005; Rudge & Howe, 2009) .Thus, the findings supported that, combination of variety of contexts for improving NOS views also influence pre-service science teachers' ability to transfer these views into instructional practices (Abd-El-Khalick, 2005, 2001; Bell, Matkins, & Gansneder, 2011).

The possible development of PCK for NOS might be also attributed to the tasks and features of the intervention related to lesson planning. For instance, in the current study, participants were supposed to create and present lesson plans where they integrate NOS explicitly. Lesson plan presentations took places in an environment where student teacher pretended like a real teacher and peers role-played students. Presentation of lesson plans which might be also inferred as microteaching served as a modelling of a NOS lesson by a peer. These modelled lessons were criticized for its strengths and weaknesses regarding NOS integration through whole class discussions. By this way, pre-service teachers had an opportunity to observe their peers modelled NOS lessons through different science contents. Modelled NOS lessons within different science content also facilitated the improvement of NOS instructional planning since the pre-service science teachers had a chance to observe the integration of NOS into science content. Moreover, follow-up discussions after the lesson plan presentations, gave an opportunity to the both presenter and the audience to reflect on their. Through the presentations and discussions, pre-service science teachers had a chance to identify and adopt resources for effective NOS instruction. In addition, discussion sessions provided a chance for reflection on NOS teaching which led improvement for NOS teaching and motivation to teach NOS (Akerson, Cullen, & Hanson, 2010). Conclusively, preparation and presentation of lesson plans followed by class discussions provided pre-service science teachers with developed teaching skills regarding NOS teaching. These results were compatible with the research suggesting that modelled NOS lessons, one to one correspondence and feedback and reflection were influential in enhancing pre-service science teacher's instructional practices (Abd-El-Khalick, 1998; Abd-El-Khalick, 2005; Akerson & Abd-El-Khalick, 2003; Akerson & Hanuscin, 2007; Akerson, Cullen, & Hanson, 2010; Akerson, Donlley, Riggs, & Eastwood, 2012; Hanuscin & Lee, 2009).

Another possible reason for the improvement in explicit reflective NOS instructional planning might be the nature of the intervention which provided extended and multiple opportunities of planning NOS in an explicit and reflective way within variety of science content. To be able to deploy NOS conceptions, pre-service science teachers needed support and to be involved in situations including planning teaching of new content (Brown, Collins, & Duguid, 1989; Wahbeh, 2009). Several researchers argued that teachers' practice of designing lessons is closely related to their ability to use personal resources and curriculum to make feasible adaptations to curricula to design powerful learning opportunities for students' learning (Bayer & Davis, 2009; Davis, 2006; Hanuscin, Lui, & Akerson, 2011). In that sense, preparing around five lesson plans within different science content and getting feedback from these lesson plans enabled them to drill NOS instructional practice in variety of science content. As a result, they gained necessary skill to translate this knowledge into their instructional practices which requires ability to either adapt or design effective NOS integrated science lessons (Akerson, Buzelli, & Donnelly, 2010; Bell, Matkins, & Gansneder, 2011; Hanuscin, Lui, & Akerson, 2011). The opportunities provided through the current intervention enabled pre-service science teachers to learn how to adapt curricular material to address NOS effectively in their planning.

Another important finding of the study came out to be the science content that the participants chose to integrate NOS. Although they were free to choose any science content, majority of them chosen science content as Atom Models, Solar System, and Cell and Inheritance at least one of the lesson plans. Through the contextualized explicit reflective NOS instruction, participants were introduced examples of atom models, an example related to DNA (Chargaff rules) and an example of pluton was a well-known example from science textbooks and science magazines. These examples may contributed to their knowledge regarding NOS and also familiarize these contexts regarding NOS. Additionally, it might be concluded that examples of these topics also contributed their subject matter knowledge on these science contents. As a result, pre-service science teachers might perceive these contents as safe zone and tended to choose these topics to address NOS since lack of subject matter knowledge was considered to be one of the constraints that hinder them integration NOS effectively (Abd-El-Khalick, & Akerson, 2003; Schwarzt, & Lederman, 2002).

Regarding the development of lesson plans related to NOS assessment, analysis of lesson plans also revealed improvements for the NOS assessment. Majority of the pre-service science teachers did not consider assessing NOS until the last two lesson plans. Towards the last lesson plans, majority of the participants used specific assessment strategies other than formative assessment for NOS. But two of the participants did not include any assessment strategies. Among the ones who considered NOS assessment used variety of strategies including poster creation, reflection paper writing, and concept map creation and giving homework. This finding was compatible with the work of Akerson, Buzelli, and Donnelly (2010) which investigated the assessment strategies used by teachers at different grade levels. They concluded that teachers used strategies such as journal writing, adaptation of the VNOS questionnaire, and drawings. Authors attributed the variety of assessment strategies used by teachers to their creativity as well as the practice of planning, implementing and analysis of the assessment tools. For instance, in the current study, participants had given opportunities to think on how to assess NOS, and to plan on NOS assessment through lesson plan preparation. These opportunities contributed to their development of PCK for NOS assessment. The two participants who did not consider assessing NOS stated that they needed to assess NOS understanding of students in their lesson plans, but they did not know how to do so. That indicated that they lacked of PCK for NOS assessment and they might need more specific learning experiences targeting to enhance knowledge for NOS assessment (Hanuscin, & Lee, Akerson, 2010). However, these participants could be able to plan NOS explicitly and reflectively which was compatible with the fact that development of PCK is uneven. That is, one could improve PCK for instructional strategies of NOS but might need more support for the development of other components of PCK for NOS (Akerson, Buzelli, & Donnelly, 2010; Hanuscin, & Lee, Akerson, 2010).

One of the most important findings of the study was the lack of pattern between NOS understanding of participants and translation of this understanding into instructional plans. The result confirmed the fact that improved NOS views is important but not sufficient for translation of these views into instructional practices (Abd-El-Khalick, & Lederman, 2000; Lederman, 1999; Lederman, 2007). Even all of the participants achieved informed understanding of the all NOS aspects, none of the participants attempted to address socio-cultural and inferential NOS in their lesson plans. Majority of the participants mostly chose to address empirical, tentative and subjective NOS in their lesson plans. Researchers argued that participants' level of comfort feeling with their NOS understanding was the one of the reason mediate their NOS instructional practices (Schwartz & Lederman, 2002; Akerson, Cullen, & Hanson, 2009). In current study, the learning experiences provided by the intervention might develop more favourable beliefs related to teaching of empirical, tentative and subjective NOS aspects. Another reason for mostly addressing these aspects in instructional plans might be the contextual nature of NOS learning. That is, the activities, examples and other learning opportunities in sum context of the intervention might provide better opportunities for the development of knowledge of NOS teaching (Abd-El-Khalick, 2001; Wahbeh, 2009).

5.1.3. Discussion of the findings for the learning experiences contributed to the pre-service science teachers' development of NOS instructional planning

In this part, I discussed findings related to the perceived sources provided within the intervention which participants attributed to their development in NOS instructional planning.

Researcher used several strategies to improve participants' NOS instructional plans such as feedback to lesson plans, HOS based examples coupled with NOS explicitly followed by NOS discussions, and lesson plan presentations followed by NOS discussions. To understand the relative importance of these learning experiences, researcher conducted interview with the participants. Analysis of interview revealed that almost all learning experiences were appreciated by pre-service science teachers as they facilitated their NOS instructional planning. However, majority of them perceived that lesson plan presentations followed by the discussions were the main source contributing their NOS instructional planning. That is, lesson plan presentations provided them as anopportunity which was close to authentic teaching opportunity, in which pre-service science teachers pretended like a real teacher and peers role-played students.Through this opportunity participants had chance to think themselves as a real teacher and think about their NOS teaching experience. Additionally, these lesson plan presentations also served as NOS modelled lessons for the rest of the participants. These teaching experience and modelled lessons were the crucial components for the development of NOS teaching knowledge (Abd-El-Khalick, 1998; Abd-El-Khalick, 2005; Akerson & Abd-El-Khalick, 2003; Akerson, Cullen, & Hanson, 2010; Akerson, Donlley, Riggs, & Eastwood, 2012; Akerson & Hanuscin, 2007; Hanuscin & Lee, 2009). All these lesson plan presentations were followed up by whole class discussions related to the strengths and weaknesses of the NOS lesson modelled. These discussion sessions gave opportunities for reflection on NOS teaching for both the presenter of the lesson plan and the other pre-service science teachers. Reflection opportunities were the crucial for the development of NOS teaching. It was argued that teachers who were more reflective were more likely to better integrate NOS into their lessons. Moreover, reflection provided motivation for NOS teaching and improved NOS teaching (Akerson, Cullen, & Hanson, 2009, 2010; Akerson, et al., 2012).

5.2. Conclusion

In the current study, how pre-service science teachers changed their NOS views in a HOS contextualized explicit reflective NOS instruction, development of NOS instructional planning, and the learning experiences contributed to their NOS instructional planning were explored. Findings of the study concluded that pre-service science teachers' NOS understanding and NOS instructional practices were contextualized. Related to NOS understanding, the current study showed that, contextualized explicit reflective NOS instruction combined various contexts were influential to gain desired understanding of NOS. The content- rich context embodied science content, HOS and decontextualized NOS activities increased the effectiveness of explicit-reflective NOS instruction resulted in informed views of pre-service science teachers.

For the translation of the NOS views in instructional practices, the pre-service science teachers revealed substantial improvements. Findings confirmed that informed NOS views did not guarantee the translation of these views into practice. Thus, there have been no clear-cut relationships between NOS views and NOS instructional practices. Findings showed that combination of decontextualized (e.g. content generic) and contextualized (e.g. science content, HOS) explicit reflective NOS activities have facilitated pre-service science teachers' translation of their e views into instructional practices. Therefore, context in which pre-service science teachers learn NOS have come out important factor playing role in translation of NOS views into instructional practices. Additionally, pre-service science teachers to be successful NOS implementers, they need contexts which provided them reflection and feedback opportunities. Reflection opportunities and feedback have been found to be important components of NOS teaching contexts resulting in favorable changes in NOS instructional practices. NOS modeled lessons, practice of NOS instructional planning within different science content have been also considered as other important components to enhance pre-service science teachers' NOS instructional planning. In that sense, NOS lesson planning and NOS modeled lessons have provided pre-service science teachers with opportunities of authentic experiences resulting in development of their knowledge of teaching NOS.

5.3. Implications of the study

The present study has several implications for pre-service and in-service teacher professional development, science teacher educators and curriculum developers based on the findings derived from the study.

The findings of the study revealed that, pre-service science teachers' NOS understanding and NOS instructional practices were context dependent. Pre-service science needed to be provided contextualized opportunities to improve their NOS views and NOS instructional practices. For that reason, contextualized NOS instruction needed to involve NOS learning and NOS teaching experiences in variety of science content. NOS learning experiences would involve having combination of content generic NOS activities, HOS examples, inquiry based examples and science content embedded examples. Regarding NOS teaching opportunities in a contextualized setting, pre-service science teachers are needed to design and critique NOS lessons. They need to observe NOS modelled lessons. Additionally pre-service science teachers should be provided with feedback based on their experiences on designing and teaching NOS lessons.

More specifically, regarding NOS understanding, science teacher education programs for pre-service science teachers and professional development programs for in-service teachers should involve combination of variety of contexts which facilitates meaningful NOS understanding. Combination of contexts ranging from decontextualized activities towards more contextualized explicit reflective NOS instruction is better to enhance NOS understanding and translation of these understanding into instructional practices. The variety of contexts could include content generic activities, examples from HOS and examples from science content coupled with explicit reflective NOS instruction. In addition, context should also provide specific pedagogical practices such as planning, presenting and discussing NOS lessons. These specific pedagogical practices give both pre-service science teachers and in-service science teachers structured opportunities to reflect on their NOS conceptions and also assess their NOS conceptions in the context of science content. Moreover, all these contextualized learning experiences should underscore reflection component strongly. Reflection is one of the key factors enabling pre-service and in-service science teachers to understand how their experiences in variety of context related to nature of science. In addition, it is recommended that pre-service science teachers should engage in learning and teaching situations in which they engaged in reflection opportunities on their NOS instructional practices and also get feedback. It is argued that reflection lead better and responsive teaching and teachers who are reflective in nature are more likely to apply newly learned strategies in their instructional planning (Akerson, Cullen, & Hanson, 2010; Akerson, Donelley, Riggs, & Eastwood, 2012; Hanuscin & Lee, 2009). In that sense, professional development programs should involve reflection opportunities on NOS instructional practices of pre-service science teaching which favoring motivation and development for NOS instructional practices. Therefore, the current dissertation presented a good example of series of NOS lessons which enhace both NOS views and NOS teaching ability. Specifically, for Turkish context, the current dissertation provided desing of a NOS course as combining different contexts and including components such as feedback, reflection, modeled NOS lessons, and practice of designed NOS lessons to improve not only NOS views but also PCK for NOS. Furtheremore, variety of contexts for NOS designed in current dissertation also enabled science educators to be able to address NOS in different contexts such as sicence courses, NOS course other than the science method course.That is, the range of different contextualized NOS examples for both to improve NOS understanding and NOS teaching ability, different tasks aiming to improve NOS teaching ability such as NOS lesson planning, NOS lesson plan presentations provided a NOS teaching package that science educators could

Another important implication of the study is related to the translation of NOS views into instructional practices. As mentioned earlier, having informed views of NOS is important but not sufficient condition for translation of NOS views into instructional practices (Abd-El-Khalick, & Lederman, 2001; Lederman, 2007). Pre- service science teachers need to know how to teach NOS which requires PCK for NOS (Abd-El-Khalick, 2005; Akerson, & Abd-El-Khalick, 2003; Akerson, & Hanuscin, 2007). Therefore, science teacher education programs and science teacher educators need to involve structured opportunities targeting to development of knowledge for NOS teaching. In that sense, these programs should highlight continued support, feedback within highly contextualized explicit reflective NOS learning and teaching situations. Moreover, it is argued that context –rich explicit reflective NOS better facilitates teachers' translation of NOS views in instructional practices. Through these contexts it is more likely that pre-service science teachers learn variety examples from HOS and science content and gain skills to connect these examples to NOS. Therefore, such contexts are required for better development of PCK for NOS.

Lack of resources, and pressure to cover content are among the constraints impede translation of NOS views into practice (Schwartz, & Lederman, 2002). Therefore science teacher education programs and science teacher educators need to provide opportunities for improvement of the pre-service science teachers' ability to either adapt or design effective NOS integrated science lessons. In that sense, lesson plan preparation within variety of science content helps them to learn how to adapt curricular material to address NOS effectively in their practice. In sum, pre-service science teachers should be involved in planning and peer teaching task regarding NOS within their science teacher education programs. Moreover, it is also important for in-service science teachers to be able to either design or adopt existing curriculum for explicit reflective NOS teaching. Therefore, professional development programs for NOS also need to provide in-service teachers with NOS lesson designing tasks to help them learning NOS teaching.

In addition, it is important to provide both pre-service, in-service and science teacher educators with sufficient NOS learning and NOS teaching materials to enable them to address NOS learning and NOS teaching in the higher education courses. Therefore, there is a need for educative materials specifically targets to improve understanding of NOS and teaching to teach NOS. Curriculum developers need to design, more contextualized NOS activities and educative material to teach NOS teaching are needed.ın that sense, present dissertation provided a kind of educative material indicating integrating NOS into variety of contexts such as HOS, and science content which modeled the teaching of NOS with examples in different courses.

5.4. Recommendations for science education research

This study aimed to improve pre-service science teachers NOS understanding and NOS instructional planning in a contextualized explicit reflective NOS setting. Based on the findings of the present study, it could be concluded that combination of decontextualized and contextualized explicit reflective NOS approach can be helpful to develop appropriate NOS understanding. It is also clear from the present study that, feedback, reflection, designing NOS lessons and modelled NOS lessons will help better conceptualizing of NOS aspects and better ability to teach NOS. Implications of the study raised several issues for future research. First, considering contextual nature of NOS learning and teaching, it would be beneficial to compare and contrast different kind of explicit reflective NOS contexts in terms of their effectiveness regarding facilitating NOS understanding. Additionally, it might be useful to explore if the effectiveness of contexts for developing NOS understanding varies regarding in-service and pre-service science teachers. Moreover, there is a need to investigate how long both pre-service science teachers and in-service science teachers retain their appropriate NOS views gained through contextualized explicit reflective NOS instruction.

A second important question needs further investigation is how pre-service science teachers NOS conceptions would translated into teaching after involved in contextualized explicit reflective NOS instruction. Also it would be valuable to explore how in-service science teachers' NOS conceptions and NOS teaching practice would be change within a highly contextualized explicit reflective NOS instruction.

Finally, further investigation is needed to explore how teachers' contextualized NOS instruction would influence variety of grade level students' understanding of NOS and levels conceptions of NOS in relation to motivational factors for learning science. Regarding developing students' NOS conception, further research needed to explore how contextualized explicit reflective NOS instruction leads more appropriate NOS views.

In sum, more research is needed to explore the complex relationship between teachers' NOS conceptions, translation of these conceptions into practice and the relationship between NOS instructional practices and students' NOS concepts.

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APPENDICES

APPENDIX A

VIEWS OF NATURE OF SCIENCE QUESTIONNAIRE

(VNOS D +)

Name: ________________________________

Date: /   /

Did you take this course before: Yes❑ NO❑

CPA   ……..

Age   …….

Sex: Female❑ Male❑

What is your current year of study at METU: ❑3year   ❑4 year

Did you take any course related with Nature of Science before: Yes❑   NO❑

Instructions

- Please answer each of the following questions. You can use all the space provided and the backs of the pages to answer a question.
- Some questions have more than one part. Please make sure you write answers for each part.
- This is not a test and will not be graded. There are no “right” or “wrong” answers to the following questions. I am only interested in your ideas relating to the following questions.

1. What is science?

2. What makes science (or a scientific discipline such as physics, biology, etc.) different from other subject/disciplines?

3. Does the development of scientific knowledge always require experiment?

   If yes, explain why. Give an example to defend your position.

4. Scientists produce scientific knowledge. Do you think this knowledge may change in the future? Explain your answer and give an example.

5. (a) How do scientists know that dinosaurs really existed?

(b) How certain are scientists about the way dinosaurs looked?

(c) Scientists agree that about 65 millions of years ago the dinosaurs became extinct (all died away). However, scientists disagree about what had caused this to happen. Why do you think they disagree even though they all have the same information?

6. In order to predict the weather, weather persons collect different types of information. Often they produce computer models of different weather patterns.

(a) Do you think weather persons are certain (sure) about the computer models of the weather patterns?

(b) Why or why not?

7. What is a scientific model?

8. Scientists try to find answers to their questions by doing investigations / experiments. Do you think that scientists use their imaginations and creativity when they do these investigations / experiments? **YES** **NO**

a. If **NO**, explain why?

b. If **YES**, in what part(s) of their investigations (planning, experimenting, making observations, analysis of data, interpretation, reporting results, etc.) do you think they use their imagination and creativity? Give examples if you can.

9. a) What is theory? After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?

b) What is law? After scientists have developed a scientific law does the law ever change?

c) Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example

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.

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

APPENDIX B

INTERVIEW QUESTIONS CONDUCTED AFTER NOS INSTRUCTION

1. How do you think students' learning about NOS? Why do they need to learn NOS in your opinion?
2. How nature of science reflected in Turkish science curriculum?
3. Do you think you would prefer to teach NOS when you will be a teacher? If so, while you are teaching NOS what kind of strategies you prefer to follow and what strategies should be followed in your opinion?
4. Could you evaluate your development for the lesson plans you prepared regarding of objectives part, activities you used and assessment on the basis of NOS teaching? What difficulties did you face with while planning for NOS?
5. Several strategies such as giving feedback for lesson plans, providing HOS examples in class and asking you to prepare and present lesson plans which was followed by class discussions were applied during the intervention. Which of these activities do you think influence your skills regarding NOS instructional planning?

APPENDIX C

LESSON PLAN SAMPLES

a) **The sample of lesson plan categorized as "poor"**

Topic: Reproduction and Growth /Cell theory

Grade level: 6^{th} grade level

Resources: Text book, http://www.biologyreference.com

Objectives: Students will be able to;

1. Explain development stages of cell theory.
2. Distinguish between cell proposals.
3. Illustrate different proposals of cell theory.

Teaching methods: direct instruction, questioning.

Connection with other subjects: SPS 1, 2, 3 are related. These require knowledge of microscope invention.

Starting: I will ask students to tell what they know about cell theory.

- ➢ Who had state cell definition first?
- ➢ Is there any idea about cell before microscope invented?

- Robert Hook is the first person who define cell in 1665.
- Although there are some thoughts about subunit (atomistic) that constitute living thing they did not describe cell. Instead they give information about atom or very small particles for everything.

This part will help student to recall their pre knowledge's.

Middle: I will teach cell theory in a gradual manner, starting from Robert Hook.

- Robert Hook used microscope and made some observations. At result he stated his observations as: there are some open spaces which are empty. He and some other scientists suggest that these spaces might be used for fluid transport in living plants.

- What have made Hook and other scientist here? Which SPS is this?
- What could be the consensus for cell theory related to Hook’s study?
- Almost all biologists at that time convinced that organisms were composed of some type of fundamental unit, and it was the atomistic perception that drove them to look for such units.
- The knowledge appeared at that time is affected by communication between different scientists and the social embedded ness appears here.
- They made inferences depending on limited data.

- In 1676, Dutch microscobist Antony Van Leuwenhoek observed red blood cell for the first time. This ne w information support Hooks’ definition.
- In 1824, Frenchman Henri Milne- Edwards propose uniform size for these globules (cell). He said that “It is clear that cell constitutes the basic unit of the organized state; indeed, everything is ultimately derived from the cell.”

François Raspail ringed the idea of Edwards as: Everything derived from old cell. But the mechanism he described was wrong.

This information also supports Hooks’ definition of cell.

- In 1832, Barthelemy Dumortier observed mid- line partition between the original cell and the new cell. After this observation Barthelemy rejected the idea that cells arise from old cells.(subjectivity of scientific knowledge)
- In 1838, Schliden proposed that a plant composed of cell or cell products. And he support Barthelemys’ idea that cells arise by crystallization- like process in cell or out of cell.

- Which idea is more accurate?

Schlieden did not make enough observations and drive such a wrong conclusion.

- In 1839, Schwann made generalization for laws governing cells identical for plant and animal. He also support Schlidens’ idea that organisms composed of cell or cell products. (for animal)
- In 1852, Robert Remark generation schemes of Schkiden and Schwann. He said that binary fusion was the means of reproduction of new animal cells. (Tentativeness of knowledge)
- In 1879, Walther Flemming noted that chromosomes split longitudinally during mitosis. Also Wilhelm Roux said that each chromosome carried a different set of heritable elements and he support Flemmings’ proposals with this idea. In 1904, Theodor Boveri confirmed this scheme. These discoveries are made by Mendel in 1866 also and these three scientists confirmed Mendel’s hereditary laws.

End: I will make a brief summary of the cell theory and finish lesson.

As much as new information gathered the cell definition that now is stated. In next century great development are recorded by invention of electron microscope.

Cell theory now stated as:

1. All living organisms are composed of cell.
2. All cells come from pre existing cells.

References:http://www.biologyreference.com, http://www.whfreeman.com/thelifewirebridge2/ (bilogy text book)

b) The sample of lesson plan categorized as "needs development"

Title/Topic: Atom and Atom Models

Grade Level: 6th grade Duration: 20 minute

Resources/materials: Some sugar and a glass of water

Objectives:

- ❖ Students will be able to identify that all matters consist from hardly indivisible and invisible particles.
- ❖ Students will be able to experiment that matters can be divided invisible small particles.
- ❖ Students will be able to define atom as building blocks of matter.
- ❖ Students will be able to differentiate that ideas related to atom structure have changed through history.
- ❖ Students will be able to recognize that atoms are also composed of small particles.

Teaching Method: Questioning and direct instruction

Connection with other subjects: This subject has connection with squeezing and expansion characteristics, element and molecule concepts and change of state of matters.

Science process skills: Observation, prediction, stating hypothesis

Related NOS Aspects: Subjectivity and tentativeness

- o How does this content portray the nature of science?

I will mention about some scientists atom models and I will emphasize that how this models change through the history. I will say that scientific knowledge can change as the time goes and it shows tentative characteristic of nature of science.

- o How can this lesson be changed so it better illustrate the nature of science?

I have not got any idea for better illustration of nature of science for this lesson.

- o What questions will you ask to facilitate student understanding of NOS?

I am planning to ask some questions such as ‘what do you think about changing of atom models through time?’ , ‘What can be the reason for changing of atom models’ etc..

Activities (Description of procedures):

- Starting:

At the beginning of our lesson I will prepare a solution. Firstly, I put a glass of water and I will show some sugar. I will want students to observe them. After that I am going to want them make some predictions about what will happen if I mix water and sugar. Then I will mix the water and sugar and ask what happened to sugar? I will said that sugar divide its small particles in the water and this particles are invisible. I will want them to state a hypothesis for this experiment. With this experiment, students will use science process skills such as observation, prediction and stating hypothesis.

- Middle:

I will define the atom as building blocks of matter. After that, I will mention Dalton, Thomson, Rutherford and Bohr Atom Models. I will say that as the time goes, the ideas related to atom structure has change. I will ask students that what characteristic of nature of science is related to changing of ideas of atom structure through history.

- End:

I will summarize the lesson and I will mention about the subject of our next lesson which is elements and molecules.

Evaluation: I will evaluate students according to their performance during the lesson.

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http://www.fenokulu.net/portal/Ogrenci.php

c)The sample of lesson plan categorized as “exemplary”

Title/Topic: Lifting Force of Liquids

Grade Level: 8th Duration: 30 minute

Resources/materials: a text book, readings

Objectives:

- Students will be able to define what lifting force is.
- Students will be able to describe the relationship between the lifting force that affect a matter and this matter’s density.
- Students will be able to describe the relationship between the lifting force that affect a matter and this matter’s volume that sink.
- Students will be able to measure the density of a matter by using its mass and volume.
- Students will be able to compare the lifting force that affects different matters with different density.
- Students will be able to indicate that how Archimede find lifting force.
- Students will be able to state the role of creativity in development of scientific knowledge.(creativity aspect of NOS)
- Students will be able to state the role of observations and experiments in development of scientific knowledge. (empirical-based aspect of NOS)

Teaching Method: Questioning, direct instruction

Connection with other subjects: This subject is connected with the unit of ‘Let’s Recognize the Matter’ from 4th grade and the unit of ‘Alteration and Recognition of Matters’ from 5th grade.

Science process skills: Observation, prediction, communication

I want to start my lesson with an activity. In this activity, I will give students a wood piece, a stone, a key and a plastic bottle. Also I will give them a bucket of water. Then I am going to ask them what will happen if we throw these materials to water. I will want them to make some predictions about which ones sink in water and which ones float in water. This will improve their prediction skills. Then we throw the materials inside of the water and observe what happened. This will improve their observation skills. At the end of this activity, I will want students to discuss about why key and stone sink while wood piece and plastic bottle float to improve their discussion skills.

Related NOS Aspects: Creativity and empirical-based

I am planning to give a text related to Archimede's life and how did he find lifting force principle. In this text I wrote that King Hiero II had wanted Archimede to search whether his crown had been made by pure gold or not. While he was in bath he noticed that the level of the water rise in the pool as he got in, and realized that this effect could be used to determine the volume of the crown. He thought that one matter that inside water displaces an amount of water that is equal to its volume. Therefore crown would displace an amount of water equal to its own volume. Immediately he design an experiment and he drop the crown in to the water and measure the volume of water that crown displaced. By dividing the weight of the crown by the volume of water displaced, he found the density of crown which is lower than the actual value of gold. With studying this text I am planning to emphasize some NOS aspects such as creativity and empirical-based. I am planning to ask these questions for emphasize creativity:

- Why did Archimede find lifting force while any other scientist did not?
- Did his creativity affect his study related to lifting force?
- Did scientist use their creativity and imagination during their investigations?
- When do scientists need to use their creativity?
- In every step of science process skills do scientists use their creativity?

For emphasizing empirical-based aspect I am planning to ask these questions:

- What did Archimede do for supporting his idea?
- Did he do some experiments?
- Do all of the scientists do experiments for their study?
- Is experimentation only route of getting scientific knowledge?

Activities (Description of procedures):

Starting: I am planning to make a review about our previous lesson which is about the properties of matters. Then I am going to start lesson with an activity. In this activity, I will give students a wood piece, a stone, a key and a plastic bottle. Also I will give them a bucket of water. Then I am going to ask them what will happen if we throw these materials to water. I will want them to make some predictions about which ones sink in water and which ones float in water. Then we throw the materials inside of the water and observe what happened. At the end of this activity, I will want students to discuss about why stone and key sink while wood piece and plastic bottle float.

Middle: I will talk about that if a matter's density is lower than the fluid's density that it is inside, this matter float in this fluid. If a matters density is higher than the fluid's density that it is inside, the matter sink in this fluid. In our activity key and stone sink in water because their density is higher than the water's density. However, wood piece and plastic bottle sink in water because their density is lower than water's density. We can find their density by dividing their mass to their volume. Some amount of lifting force exerted on these matters. Lifting force is the force that is exerted to a matter because of its volume and it is direction is always opposite to weight of this matter. Then I will mention that one matter that inside of a fluid displaces an amount of fluid that is equal to its sunken volume. The amount of lifting force that is exerted to matter by fluid is depends on fluids density. As fluid's density rise lifting force that is exerted to matter increase as well. After mentioning these I will give a text about Archimede who suggest the idea of lifting force of liquids. I will want them to read the text below.

Archimede was born in Sicilia in 287 BC and dead in 212 BC. He was a Greek mathematician, physicist, engineer, inventor, and astronomer. He is famous with his lifting force principle. One day King Hiero II suspected about the crown that he had been made may be not from pure gold. He invited Archimede and asked to determine whether it was of solid gold, or whether silver had been added by a dishonest goldsmith. Archimedes had to solve the problem without damaging the crown, so he could not melt it down into a regularly shaped body in order to calculate its density. While taking a bath, he noticed that the level of the water rise in the pool as he got in, and realized that this effect could be used to determine the volume of the crown. He thought that one matter that inside water displace an amount of water that is equal to its volume. Therefore crown would displace an amount of water equal to its own volume. Immediately he design an experiment and he drop the crown in to the water and measure the volume of water that crown displace. By dividing the weight of the crown by the volume of water displaced, he found the density of crown which is lower than the actual value of gold. Therefore, it was revealed that the crown had not been made by pure gold.

Then I am planning to ask these questions to mention some NOS aspects:

- I am will ask these questions for emphasize creativity:

- Why did Archimede find lifting force while any other scientist did not?
- Did his creativity affect his study related to lifting force?
- Did scientist use their creativity and imagination during their investigations?
- When do scientists need to use their creativity?
- In every step of science process skills do scientists use their creativity?

For emphasizing empirical-based aspect I will ask these questions:

- What did Archimede do for supporting his idea?
- Did he do some experiments?
- Do all of the scientists do experiments for their study?
- Is experimentation only route of getting scientific knowledge?

According to their answers I will mention that scientist's creativity affect their investigations. In every step of science process skills scientists use their creativity such as while making observations, inferences, predictions, experiments even collecting data they use their creativity. Because different scientist may focus on different data and their interpretations may be different. Then I will talk about that for supporting his idea Archimede made an experiment. However all scientist do not use experiments while getting scientific knowledge. In some cases doing experiment may not be possible. Therefore, they can use their observations, inferences and predictions for getting scientific knowledge not only experiments.

End: At the end, I will summarize lesson. I will say that lifting force is the force that is exerted to a matter because of its volume and it is direction is always opposite to weight of this matter and one matter that inside of a fluid displaces an amount of fluid that is equal to its sunken volume. Also I am going to say that sinking and floating actions are dependent on fluid density and matter density. Then I will mention that Archimede used his creativity for his study which is about lifting force of liquids and made an experiment to support it. These show the creativity and empirical-based aspects of NOS.

Evaluation: I will evaluate students according to their performance during the lesson. I mean due to their participation of discussions in the class. Also I am planning to ask a question what we learned related to NOS? Which aspects did we cover? I will evaluate their NOS understandings related to the participants' of these questions.

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APPENDIX D

EXTENDED TURKISH SUMMARY

(Genişletilmiş Türkçe Özet)

FARKLI ÖĞRENME ORTAMLARIYLA İLİŞKİLENDİRİLMİŞ DOĞRUDAN YANSITICI YAKLAŞIMIN FEN OĞRETMEN ADAYLARININ BİLİMİN DOĞASI GÖRÜŞLERİ VE BİLİMİN DOĞASI ÖĞRETİMİNE ETKİSİNİN ARAŞTIRILMASI

Fen bilgisi eğitimin amacı bilim okuryazarı bireyler yetiştirmek olarak tanımlanmıştır. Günümüzde yaşanan hızlı ekonomik, teknolojik, sosyal ve bilimsel değişimler göz önüne alındığında, bilimsel okuryazar bireylerin önemi güçlü bir ülke oluşturmak isteyen toplumlarca anlaşılmıştır. Bu bağlamda, bilimsel okuryazar bireyler yetiştirmek fen bilimleri dersinin önemli amaçlarından birisidir. Türkiye'nin de arasında bulunduğu birçok ülke fen eğitimini geliştirmek ve bilimsel okuryazar bireyler yetiştirmek adına köklü reformlar yapmıştır. Bilimsel okuryazar birey fen kavramlarını anlayabilen, bilimsel bilgiyi bilimsel olmayan bilgiden ayıran ve bilimi sosyal bir insan aktivitesi olarak gören, bilim-toplum arasındaki ilişkiyi kavrayabilen bireyler olarak tanımlanmıştır (Driver, Leach, Millar, ve Scott, 1996). Ayıca, bilim okuryazarlığı bireylerin araştırma-sorgulama, eleştirel düşünme, problem çözme ve karar verme becerilerini, yaşam boyu öğrenen bireyler olmalarını, çevreleri ve dünya hakkında olup bitenleri merak eden ve anlayabilen bireyler olmalarını da içerir. Bilimin doğası konusunun anlaşılması bilim okuryazarlığında istenilen düzeye ulaşmak için gerekli temel şartlardan biridir (Abd-El-Khalick ve Lederman, 2000).Bireylerin bilimsel okuryazar olarak yetişebilmesi için bilimin doğası ile ilgili istenen düzeyde kavramlara sahip olması beklenmektedir. Bilimin doğası tanımı ile ilgili üzerinde uzlaşılmış ortak bir tanım olmamasına rağmen, bilimin doğası genel olarak bilim nedir ve bilimsel bilgi üretilirken nasıl süreçlerden geçer konularıyla ilgilenir (Lederman, 1992). Bilimin ve bilimsel bilginin doğası üzerinde çalışan araştırmacılar, özellikle ilköğretim seviyesinde, öğrencilerin öğrenmesi gereken bilimsel bilginin çeşitli özelliklerini şöyle açıklamışlardır (Lederman, Abd-El-Khalick, Bell ve Schwartz 2002):

1.Bilimsel Bilginin Değişebilir Doğası:

Bilimsel bilgi yeni gözlemler ve var olan gözlemlerin yeniden yorumlanması ve gelişen teknoloji ile elde edilen verilerin değişmesi veya gelişmesi ile değişebilir. Bilimsel bilgi yorumlanmış veriler ışığında güvenilir olmasına rağmen tam doğru ya da kesin değildir, her zaman değişime açıktır.

2.Bilimsel Bilgi Delile Dayalıdır:

Bilimsel bilgi, gözlem veya deneyler sonucu elde edilen deliller ile desteklenmeyi gerektirir. Bilimsel bilgi gözlem veya deney sonucu elde edilen verilerin yorumlanmasına dayalı olarak oluşturulur. Gözlem veya deney sonucunda elde edilen veriler, bilim insanının teorik, akademik ve kişisel inançlarının süzgecinden geçirilerek ve kısmen yaratıcılık ve hayal gücünden etkilenerek yorumlanır.

3. Bilimde Öznellik

Her ne kadar bilimsel bilginin objektif olması beklense de, bilimsel bilgi her zaman bilim insanının öznelliğini içerir. Bilimsel bilgi oluşturulurken, bilim insanının inançları, akademik geçmişi, beklentileri, almış olduğu eğitim ve önyargıları bilim insanının seçeceği araştırma konusunu, verileri elde etme şeklini, verileri yorumlamasını ve bilimsel bilgiyi oluşturma sürecini etkiler.

4.Bilimsel Bilginin Yaratıcı Doğası

Bilim insanı bilimsel araştırmaya başlarken, araştırmayı tasarlarken, veri toplarken, verileri yorumlarken bilimsel araştırma sürecinin her aşamasında hayal gücü ve yaratıcılığından etkilenir.

5.Bilimsel Bilginin Sosyal ve Kültürel Yapısı

Bilim içerisinde üretildiği toplumun ahlaki, kültürel, sosyal değerlerinden etkilenen bir insan aktivitesidir. Toplumun kültürel değerleri oluşturulan bilimsel bilginin kabul görüp göremeyeceğine veya bilimin nasıl ve ne şekilde yapılacağına etki eder. Bunlara ek olarak bilimsel bilgi içerisinde üretildiği toplumun kültürel, politik, sosyal değerlerini de etkileyebilir.

6. Gözlem ve Çıkarım

Bilimsel bilgi gözlem ve deneyler sonucu elde ettiğimiz verilerin yorumlanmasına dayanır. Bilimsel bilgi oluşturulurken bilim insanları gözlem ve deneylere dayalı olarak çıkarımlarda bulunurlar.

7.Bilimsel Teoriler ve Kanunlar:

Teoriler ve kanunlar birbirinden farklı bilimsel bilgilerdir. Teoriler ve kanunlar birinden diğerine dönüşmezler, aralarında hiyerarşik bir ilişki yoktur. Kanunlar; doğada gözlemlenen ilişkilerin tanımlanmasıyken, teoriler doğal olgular arasındaki ilişkinin açıklanmasıdır. Yeni deliller ışığında veya bilim insanlarının var olan verileri yorumlamasının değişmesi sonucu hem teoriler hem kanunlar değişebilirler.

Fen eğitimin amacının bilimsel okuryazarlık olarak belirlenmesi ve bilimin doğasının bilimsel okuryazar bireyler yetiştirmede önemi vurgulanmış olsa da, yapılan birçok çalışma çeşitli düzeylerdeki öğrencilerin yetersiz sevide bilimin doğası görüşlerine sahip olduğunu göstermiştir (Dogan ve Abd-El-Khalick, 2008; Akerson, Nargung-Johsi, Weiland, Pongsanon, ve Avsar, 2013; Abd-El Khalick ve Lederman, 2000). Fen eğitimi programında yeterince bilim felsefesine yer verilmemesi, bilimin doğası ile ilgili kavramların açık bir biçimde vurgulanmaması, pozitivist yaklaşımı benimseyen deney ve etkinlikler öğrencilerin bu yetersiz görüşlerine sebep olarak ileri sürülmektedir (Abd-El-Khalick ve Lederman, 2000; Lederman,2007). Bu faktörlerin yansıra, öğrencilerin sahip oldukları yetersiz görüşlerde öğretmenlerinde önemli bir rolü vardır. Öğrencilerin bilimin doğası ile ilgili yeterli görüşler geliştirebilmesi için, açık, yansıtıcı yaklaşımla bilimin doğası öğretimine ihtiyaç vardır. Bununla birlikte, yapılan çalışmalar, fen öğretmenlerinde bilimin doğası ile ilgili yetersiz görüşlere sahip olduğunu ortaya çıkarmıştır (Abd-El-Khalick, 2005; Akerson ve Abd-El-Khalick, 2000; Akerson ve Donnely, 2010; Cil ve Cepni, 2012; Ozgelen, Tuzun, ve Hanuscin, 2012). Bilimin doğası ile ilgili yeterli düzeyde anlayışa sahip olmayan fen öğretmenlerinin, bilimin doğasını sınıf içinde doğru bir biçimde öğrencilerine aktarması beklenemez (Lederman, 1999; Akerson ve Abd-El-Khalick, 2003; Bell, Matkins, ve Gansneder, 2011; Akerson ve Volrich, 2006; Demirdogen, 2012). Bu nedenle, fen öğretmenlerinin ve öğretmen adaylarının öncelikle yeterli düzeyde bilimin doğası kavramlarını geliştirmesi gerekir (Lederman, 2007).Bununla birlikte, yapılan çalışmalar öğretmenlerin yeterli düzeyde bilimin doğası görüşüne sahip olmasının bilimin doğasını sınıf içinde doğru bir biçimde anlatabileceğini garanti etmemektedir (Abd-El-Khalick ve Lederman, 2000; Lederman, 2007). Öğretmen ve öğretmen adaylarının bilimin doğasını anlatabilmek için bilimin doğası ile ilgili pedagojik alan bilgisine ihtiyaçları vardır. Bu bilgi bilimin doğası konusu ile ilgili yeterli anlayışın yanında, bilimin doğasını öğretebilmek için yeterli örnek, değerlendirme stratejisi ve öğretim yöntemleri bilgisine sahip olmayı içerir (Lederman, 2007; Akerson & Volrich, 2006; Akerson, Cullen, & Hanson, 2009). Bilimin doğasını nasıl öğreteceğini bilmeyen öğretmen ve öğretmen adayları, yeni hazırlanmış öğretim programında da önemi vurgulanan bilimsel okuryazarlık hedefine ulaşmada engel oluşturacaktır. Bilim okuryazarı bireyler yetiştirmek için yapılan reformların sonuç vermesi geleceğin fen öğretmenlerinin bilimin doğasını yeterli bir biçimde anlayabilmesi ve öğretebilmesine bağlıdır. Bu bağlamda, öğretmen eğitim programlarına önemli bir rol düşmektedir.

Bu çalışmanın amacı Fen öğretmen adaylarının bilimin doğası görüşlerini ve bilimin doğası öğretime yönelik becerilerinin farklı öğrenme ortamlarıyla ilişkilendirilmiş öğretim yöntemleri dersinde geliştirilmesidir. Çalışmanın araştırma soruları aşağıdaki gibidir:

1-Fen öğretmen adaylarının bilimin doğası ile ilgili görüşleri farklı öğrenme ortamları ile ilişkilendirilmiş açık yansıtıcı yaklaşım sonucu nasıl bir değişim göstermektedir?

2-Fen öğretmen adaylarının bilimin doğası ile ilgili ders planları farklı öğretim ortamları ile ilişkilendirilmiş açık yansıtıcı yaklaşım ve geri dönüt sonucu nasıl bir değişim göstermektedir?

3-Fen öğretmen adaylarının bilimin doğası ile ilgili ders planlarının değişimine ne tür öğrenme deneyimleri katkıda bulunmuştur?

YÖNTEM

Araştırma Deseni:

Fen öğretmen adaylarının, bilimin doğası ile ilgili görüşlerinin geliştirilmesi, bilimin doğası ile ilgili ders planlarının geliştirilmesi ve bu gelişime katkı sağlayan öğrenme deneyimlerini araştırmak için nitel araştırma yöntemleri kullanılmıştır. Bu çalışma bir yorumlayıcı nitel çalışma çeşididir (Merriam, 2009). Nitel çalışmanın doğasına uygun olarak, Fen öğretmen adaylarının, bilimin doğasına yönelik oluşturdukları anlam ve anlayışlar ve bu kavramla ilişkili olan deneyimleri araştırılmıştır. Bu amaçla, yüz yüze görüşme, belge incelemeleri gibi yöntemlerle veri toplanarak, Fen öğretmen adaylarının bilimin doğası görüşleri ve bilimin doğasına ilişkin ders planları ayrıntılı bir biçimde betimlenmiştir.

Katılımcılar:

Bu araştırmanın katılımcıları Ankara da bulunan büyük bir devlet üniversitesinde İlköğretim Fen Bilgisi Öğretmenliği programına kayıtlı yedi üçüncü sınıf öğrencisinden (6 kadın, 1 erkek) oluşmaktadır. Katılımcıların yaşları 21-26 yaş aralığında değişmektedir. Tüm katılımcılar akademik olarak benzer geçmişe sahiptir. Katılımcıların hepsinin 92 kredilik ders yükünü tamamlama sorumluluğu vardır ve bu kredi yükünün 45 kredisi fizik, kimya biyoloji gibi alan derslerinden oluşmaktadır. Katılımcılar bu 45 kredilik alan derslerini kayıtlı oldukları programın ilk iki yılında tamamlamıştır. Katılımcıların tamamlaması gereken diğer ders yükümlükleri genel eğitim pedagojisi ile ilgili derslerdir. Bu dersler, eğitim psikolojisi, eğitimde ölçme değerlendirme, öğretim yöntemleri gibi derslerden oluşmaktadır. Katılımcılardan hiçbiri daha önce bilimin doğası ile ilgili veya bilimin doğası ile ilişkilendirilmiş bir ders almamıştır.

Veri Toplama Araçları:

Bu çalışmada veri toplama araçları, çalışmanın nitel doğasına uygun olarak seçilmiştir (Merriam, 2009). Genel olarak araştırma soruları, yarı-yapılandırılmış görüşme, açık uçlu Bilimin Doğası Görüşler anketi (Lederman, Abd-El-Khalick, Bell, ve Schwartz, 2002), öğrenci yansıtıcı rapor ve ders planları ile araştırılmıştır.

Bilimin DoğasıGörüşler Anketi (VNOS-C) : Katılımcıların bilimin doğası ile ilgili görüşlerini araştırmak için Lederman, Abd-El-Khalick, Bell, ve Schwartz (2002) tarafından geliştirilen ve 10 açık uçlu sorudan oluşan anket uygulanmıştır. Bilimin doğası alanında çalışan birçok araştırmacı doğru-yanlış, çoktan seçmeli veya likert tipi ölçme araçlarının katılımcıların kendilerini ifade etmelerini sınırlayacağını belirtmiştir. Bu nedenle, açık uçlu ölçme araçlarının bilimin doğası ile ilgili görüşleri daha anlamlı ve derinlemesine araştıracağını savunmuşlardır (Lederman, Abd-El-Khalick, Bell, ve Schwartz, 2002; Schwartz ve Lederman, 2002; Schwarzt, Lederman, ve Crawford, 2004; Akerson, Buzelli, ve Donnelly, 2008). Buna ek olarak, anketi geliştiren araştırmacılar katılımcılarla açık uçlu sorulara verdikleri cevaplarla ilgili yüz yüze yarı-yapılandırılmış görüşmeler yapmanın kişilerin bilimim doğası görüşleriyle ilgili daha detaylı bilgi verecegini öne sürmüştür (Lederman, Abd-El-Khalick, Bell, ve Schwartz, 2002). Tablo1.kullanılanBilimin Doğası Görüşler Anketi (VNOS-C) anketindeki her bir sorunun bilimin doğası ile ilgili hangi boyutu araştırdığını göstermektedir:

Tablo 84. Bilimin Doğası Görüşleri Anketi soruları ve ilgili boyutlar

Soru numarası	Bilimin doğası boyutları
1	Bilimle ilgili genel fikirler
2	Bilimsel bilginin delile dayalı yapısı
3	Bilimsel deneylerin doğası ve rolü
4	Bilimsel bilginin değişebilirliği
5	Öznellik, Bilimsel bilginin çıkarımsal yapısı, bilimsel bilginin değişebilirliği
6	Bilimsel bilginin çıkarımsal yapısı, bilimsel bilginin değişebilirliği, Bilimsel modeller
7	Bilimsel modeller, Bilimsel bilginin çıkarımsal yapısı
8	Bilimsel bilginin yaratıcı doğası
9	Kanun ve teoriler
10	Bilimsel bilginin sosyal ve kültürel yapısı

Yarı-yapılandırılmış görüşmeler: Yarı-yapılandırılmış görüşmeler bu çalışmanın başlıca veri toplama araçlarından biridir. Bu görüşmelerin iki amacı vardır. Katılımcıların bilimin doğası ile ilgili görüşleri hakkında daha detaylı bilgi edinmek için uygulama öncesi ve sonrasında gerçekleştirilmiştir (Lederman, Abd-El-Khalick, Bell, ve Schwartz, 2002; Schwartz ve Lederman, 2002; Schwarzt, Lederman, ve Crawford, 2004; Abd-El-Khalick, 1998). Bilimin doğası görüşler anketini oluşturan araştırmacılar, örneklemin en az %10-15' lik gibi bir kısmıyla yarı-yapılandırılmış görüşmeleri tavsiye etmiştir (Lederman, Abd-El-Khalick, Bell, ve Schwartz, 2002). Bu bağlamda çalışmaya katılan beş katılımcı ile gönüllülük esasına dayalı yapılandırılmış görüşmeler gerçekleştirilmiştir. Bu görüşmeler yaklaşık 30 dakika boyunca sürmüştür. Görüşmeler sırasında katılımcılara Bilimim doğası görüşler anketine verdikleri cevaplar sunulmuş ve sorulara verdikleri cevapları örneklendirmeleri, genişletmeleri veya detaylandırmaları istenmiştir.

Katılımcıların bilimin doğasına ilişkin görüşlerinin araştırılmasının yanı sıra, bilimin doğasının öğretimine ilişkin kavramlarında öğrenmek için görüşmeler düzenlenmiştir. Bu görüşmeler gönüllülük esasına göre düzenlenmiştir. Görüşmeler uygulama sonrası düzenlenmiş ve yaklaşık 25 dakika sürmüştür. Bu görüşmelerde katılımcıların, bilimin doğasının ders planlarına entegrasyonu ile ilgili sorular sorulmuştur.

Yansıtıcı rapor: Bu raporların amacı katılımcıları bilimin doğası öğretimi ile ilgili düşünmeye teşvik etmektir. Uygulama sonucunda katılımcıların bilimin doğası öğretimi ile ilgili kavramlarını anlamak adına aşağıda verilen soruları cevaplamaları istenmiştir:

d. Bilimin doğasını öğretmek gerekli midir? Cevabınızı lütfen ayrıntılı bir biçimde yazınız.

e. Gelecekte öğretmen olduğunuzda bilim doğasını öğrencilerinize öğretmeyi düşünüyor musunuz? Eğer öğretmeyi düşünürseniz, öğretmek için nasıl bir yol izlersiniz?
f. Şu anda sahip olduğunuz bilgilerinizle kendinizi bilimin doğasını öğretmek için yeterli görüyor musunuz? Cevabınızı lütfen ayrıntılı bir bicimde biçimde yazınız.

Ders planları: Katılımcıların bilimin doğası öğretme becerilerindeki değişime, yaptıkları ders planları incelenerek karar verilmiştir. Katılımcılar toplamda beş ders planı hazırlamış ve her bir plana bilim tarihi ve bilimin doğasını entegre etmeleri beklenmiştir. Katılımcılar ders planlarını hazırlarken konu ve sınıf kademe seçimine kendileri karar vermiştir. Çalışmayı yürüten araştırmacı, her bir ders planına bilimin doğası entegrasyonu açsından geri dönüt vermiştir. Çalışmada kullanılan ders planları üç ana kısımdan oluşmaktadır, konu ile ilgili kazanımlar, konu ile ilgili etkinlikler ve değerlendirme kısmı. Konu ile ilgili kazanımlar kısmında katılımcıların seçtikleri konu ve bilimin doğası ile ilgili kazanımlar yazmaları beklenmektedir. Konu ile ilgili etkinlikler kısmı, katılımcıların seçtikleri konuyu anlatmak için izleyecekleri yol, kullanacakları öğretim stratejisi, etkinlik ve örnekler hakkında detaylı bilgi verir. Değerlendirme kısmı ise, yazılan kazanımların ölçülmesine dair değerlendirmeyi nasıl yapacakları hakkında bilgi verir. Katılımcılardan ders planının bu üç kısmini bilimin doğası ile ilişkilendirmeleri beklenmektedir. Araştırmacı, katılımcılara bu yönde geri dönüt vermiştir.Tablo 2. Çalışmanın araştırma sorularını ve bu soruları araştırmak için kullanılacak veri araçlarını özetlemektedir:

Tablo 85. Araştırma soruları, veri araçları ve veri toplama süreci

Araştırma soruları	Veri araçları ve Veri toplama süreci
Fen öğretmen adaylarının bilimin doğası ile ilgili görüşleri farklı öğrenme ortamları ile ilişkilendirilmiş açık yansıtıcı yaklaşım sonucu nasıl değişmiştir.	Bilimin doğası görüşler anketi (VNOS-C) uygulama öncesi ve sonrasında uygulanmıştır Yarı-yapılandırılmış görüşmeler uygulama öncesi ve sonrasında yapılmıştır
Fen öğretmen adaylarının bilimi doğası ile ilgili ders planları farklı öğretim ortamları ile ilişkilendirilmiş açık yansıtıcı yaklaşım ve geri dönüt sonucu nasıl değişmiştir?	Ders planları toplanmıştır Uygulama sonunda yarı-yapılandırılmış görüşmeler yapılmıştır Yansıtıcı raporlar toplanmıştır
Fen öğretmen adaylarının bilimin doğası ile ilgili ders planlarının değişimine ne tür öğrenme deneyimleri katkıda bulunmuştur?	Yarı-yapılandırılmış görüşmeler uygulama sonrası yapılmıştır

Uygulama:

Çalışma kapsamında yapılan uygulama öğretim yöntemleri dersinde yapılmıştır ve 10 hafta sürmüştür. Öğretim yöntemleri dersi bilimin doğasını ders içine bütünleştiren bir yaklaşımla verilmiştir. Uygulama boyunca bilimin doğasını öğretmek amacıyla açık yansıtıcı yaklaşım farklı öğrenme ortamlarında öğretmen adaylarına verilmiştir. Bu çerçevede katılımcılara önce bir içerikle ilişkilendirilmemiş (de-contextualized) açık yansıtıcı bilimin doğası eğitimi verilmiştir. Bu uygulama toplamda dört hafta sürmüştür. Uygulama boyunca katılımcılar belli bir içerik ile ilişkilendirilmemiş sadece bilimin doğasını öğretmeyi amaçlayan etkinliklere katılmışlardır (Lederman ve Abd-El-Khalick, 1998). Bu etkinlikler boyunca katılımcılara, tartışma, bilimin doğası ile ilgili fikirlerini gözden geçirme, düzenleme ve fikirlerini diğer katılımcılarla paylaşma olanağı sunulmuştur. Tablo 3 uygulamanın ilk dört haftasında uygulanan ve bir içerikle ilişkilendirilmeyen bilimin doğası etkinliklerini ve bu etkinliklerinin amaçlarını özetlemektedir.

Tablo 3. İçerikle ilişkilendirilmemiş bilimin doğası etkinlikleri ve ilgili bilimin doğası boyutları

Haftalar	Etkinlik adı	Amaçlanan bilimin doğası boyutu
1.hafta	Bir bilim adamı çizin İddia ifadeleri	Bilim nedir, bilim insanları nasıl çalışır? Bilimsel bilgi nedir?.
2.hafta	Kart etkinliği	Bilim nedir, bilim insanları nasıl çalışır? Bilimsel bilgi nedir?
	Ayak izleri	Gözlem ve çıkarım arasındaki fark Bilimde öznellik
	Genç-yaşlı?	Bilimde öznellik Gözlem ve çıkarım arasındaki fark Bilimin sosyal ve kültürel yapısı
3.hafta	Fosiller	Bilimde yaratıcılık ve hayal gücü Bilimsel bilginin delile dayalı yapısı Bilimsel bilginin çıkarımsal yapısı Bilimde öznellik
	Tangram etkinliği	Bilimde öznellik, Bilimsel bilginin değişebilirliği Bilimde yaratıcılık ve hayal gücü Teori ve kanunlar
4.hafta	Olayları sıralama etkinliği	Bilimsel bilginin delile dayalı yapısı Bilimde öznellik Bilimin sosyal ve kültürel yapısı
	Kutunun içinde ne var?	Teori ve kanunlar Bilimsel bilginin delile dayalı yapısı Bilimde öznellik Bilimsel bilginin değişebilirliği Bilimde yaratıcılık ve hayal gücü

Uygulama da beşinci hafta içerikle ilişkilendirilmiş etkinliklere geçiş için kullanılmıştır. Bu haftada katılımcılara farklı öğrenme ortamı olarak sunulacak olan bilim tarihi tanıtılmıştır. Ayrıca, katılımcıların bilimin doğasını fen alan içeriğiyle de ilişkilendirmesini kolaylaştırma adına, katılımcılarda öğretim programını bilimin doğası entegrasyonu açısından incelenmeleri istenmiştir. Bu hafta boyunca katılımcıların bu konuları sınıf içinde tartışması sağlanmıştır.

Uygulama beşinci haftadan sonra içerikle ilişkilendirilmiş açık yansıtıcı bilimin doğası etkinlikleri ile devam etmiştir. Bu haftadan itibaren içerik olarak bilimin doğasından örnekler ve fen konu alanından örneklerle ilişkilendirmeler yapılarak bilimin doğası açık yansıtıcı bir biçimde vurgulanmıştır. Araştırmacı, katılımcılara bilim tarihinden okuma parçaları sağlamış, katılımcılar bir kavramları tarihsel yaklaşım içerisinde incelerken aynı zamanda bilimin doğası boyutları ile de ilişkilendirme olanağı bulmuştur. Katılımcılar sınıf içinde bilim tarihinden belli kavramalar ile ilgili okuma parçalarını okumuş, daha sonra sınıf içinde bu okuma parçasının bilimin doğası ile ilgili boyutları nasıl yansıttığı ile ilgili olarak sınıfiçi tartışma yapılmıştır. Uygulamada bilim tarihinden örnekler seçilmesinin sebebi, bilim tarihinin bilimin doğası ile ilgili kavramları anlamayı kolaylaştırmasıdır (Clough, 2006; Abd-El-Khalick, 2005; Kim ve Irving, 2010; Rudge ve Howe, 2009; Lin ve Chen, 2002). Ayrıca, araştırmacılar bilim tarihinin, katılımcıların bilimin doğası ile ilgili boyutları fen konu içeriği ile ilişkilendirmesini de kolaylaştıracağını öne sürmüştür (Clough, 2006). Kısaca bilim tarihi ile ilişkilendirmenin açık yansıtıcı yaklaşımın etkiliğini artıracağı öne sürülmüştür (Clough, 2006; Abd-El-Khalick, 2005; Kim ve Irving, 2010; Rudge ve Howe, 2009; Lin ve Chen, 2002). Uygulama süresince kullanılan bilim tarihi ile ilgili örnekler tablo 4.' de özetlenmiştir.

Tablo 4. Bilim tarihi ile ilgili örnekler ve ilişkilendirilen bilimin doğası boyutları

Okuma parçası	Okuma parçası içeriği	İlgili bilimin doğası boyutları
Bilim iş başında (John Lenihan,1990)	Erime ve donma noktaları kavramlarının ortaya çıkışı	Bilimsel bilginin delile dayalı yapısı Bilimsel bilginin çıkarımsal yapısı Bilimde yaratıcılık ve hayal gücü Bilimsel bilginin değişebilirliği
İkili Sarmal (James Watson,1968)	DNA ile ilgili kavramların ortaya çıkışı	Bilimin sosyal ve kültürel yapısı Bilimde öznellik Bilimsel bilginin değişebilirliği
İkili Sarmal (James Watson,1968)	Rosalind Franklin 'in DNA'in Keşfindeki rolü	Bilimin sosyal ve kültürel yapısı
Elektriğin Keşfi (http://learningscience.edu.hku.hk/Package.html)	Luigi Galvani ve Alessandro Giuseppe Volta' nin elektrik ile ilgili geliştirdiği açıklamalar	Bilimde öznellik Bilimsel bilginin değişebilirliği Bilimsel bilginin delile dayalı yapısı Bilimsel bilginin çıkarımsal yapısı

Her hafta için verilen bilim tarihi örneğini ders planı hazırlama ve sunma etkinliği izlemiştir. Her hafta katılımcılardan bilimin doğasını entegre ettikleri bir ders planı hazırlamaları beklenmiştir. Katılımcılar arasından herhangi bir katılımcı gönüllülük esasına dayalı olarak ders planını mikro öğretim yöntemiyle sunmuştur. Bu sunumları aşağıda belirtilen soruların yönlendirdiği sınıf içi tartışmalar izlemiştir:

V. Mikro öğretim boyunca hangi bilimin doğası boyutları entegre edilmiştir?
VI. Entegre edilen bilimin doğası boyutları nasıl yansıtılmıştır?
VII. Entegre edilen bilimin doğası boyutları sizce daha iyi nasıl yansıtılabilirdi?
VIII. Başka hangi bilimin doğası boyutları bu mikro öğretim örneğine entegre edilebilirdi?

Bu tartışmalar, katılımcılara öncelikle bilimin doğası ile ilgili görüşlerini yeniden gözden geçirme ve daha derin ve anlamlı bir anlayış kazanma gibi imkânlar sunmuştur. Ayrıca, katılımcılar bilimin doğası ile ilgili fen kavramları ile ilişkilendirilmiş örnekler görme fırsatı bulmuşlardır. Bilim tarihinden örnekler ve fen kavramıyla ilişkilendirilmiş örnekler, katılımcılara farklı öğrenme ortamlarıyla ilişkilendirilmiş açık yansıtıcı yaklaşımla bilimin doğası ile ilgili görüşlerini geliştirme fırsatı sunmuştur. Araştırmacılar, birleştirilmiş farklı öğrenme ortamlarıyla ilişkilendirilmiş açık yansıtıcı yaklaşımla bilimin doğası eğitiminin daha etkili olduğunu savunmaktadırlar (Abd-El-Khalick, 2001; Deniz, 2007; Ozgelen, Tuzun, ve Hanuscin, 2012; Bell, Mulvey, ve Maeng, 2012; Bell, Matkins ve Gansneder, 2011; Rude, ve Howe, 2009; Howe, 2004; Scharmann et al. 2005).

Bu çalışmada ders planı hazırlama ve ders planlarını mikro öğretim yöntemiyle sunmanın katılımcıların bilimin doğası öğretimiyle ilgili becerilerini geliştireceği varsayılmıştır. Yapılan çalışmalar, öğretmen adaylarının bilimin doğası ile ilgili öğretim becerilerinin gelişmesi için, öğretmen adaylarının bilimin doğası ile ilgili, ders planlama, örnek bilimin doğası dersleri izleme ve bilimin doğası öğretimi ile ilgili tartışma ortamlarında bulunmanın ve bilimin doğası öğretme deneyimleri ile ilgili geri dönütün gerekliliğine vurgu yapmıştır (Abd-El-Khalick, 1998; Akerson ve Abd-El-Khalick, 2003; Akerson ve Hanuscin, 2007; Abd-El-Khalick, 2005; Hanuscin ve Lee, 2009; Akerson, Donlley, Riggs, ve Eastwood, 2012; Akerson, Cullen, ve Hanson, 2010). Bunlara ek olarak, farklı öğrenme ortamlarıyla ilişkilendirilmiş açık yansıtıcı bilimin doğası öğretiminin, bilimin doğası ile ilgili görüşlerin öğretime transferini kolaylaştırdığı öne sürülmektedir (Bell, Matkins, ve Gansneder, 2011; Abd-El-Khalick, 2005, 2001; Clough, 2006; Rudge ve Howe, 2009; Dass, 2005). Bu nedenle, uygulama gerçekleştirilirken farklı öğrenme ortamları açık yansıtıcı yaklaşımla birleştirilmiştir. Aşağıda verilen tablo 5 uygulama da kullanılan içerik ile ilişkilendirilmiş açık yansıtıcı yaklaşım etkinliklerini özetlemektedir.

Tablo 5. İçerik ile ilişkilendirilmiş açık yansıtıcı yaklaşımla bilimin doğası etkinlikleri

Hafta	Alan ile ilişkilendirilmiş açık yansıtıcı bilimin doğası etkinlikleri
6 .hafta	• Bilim tarihi okuma parçası (Bilim is başında, John Lenihan,1990) • Ders planı sunumu ve tartışma
7. hafta	• Bilim tarihi okuma parçası (İkili Sarmal, James Watson,1968) • Ders planı sunumu ve tartışma
8. hafta	• Bilim tarihi okuma parçası (İkili Sarmal, James Watson,1968) • Ders planı sunumu ve tartışma
9. hafta	• Bilim tarihi okuma parçası (Elektriğin Keşfi, http://learningscience.edu.hku.hk/Package.html) • Ders planı sunumu ve tartışma
10 .hafta	• Bilimin doğası ile bütünleştirilmiş ders planı hazırlanması hakkında tartışma • Ders planı sunumu

Veri Analizi:

Çalışmada elde edilen veriler nitel veri analiz yöntemleri ile analiz edilmiştir. Nitel veriler analiz edilirken kullanılan genel yaklaşım benimsenmiştir. Veri analizi, Miles ve Huberman (1994)' in önerdiği yanıtların tekrar tekrar okunması, var olan desen ve kategoriler ile ilgili notlar alınması ve en sonunda kodlar oluşturması seklinde gerçekleşmiştir. Veri analizinde geçerlilik ve güvenirliği sağlamak adına oluşturulan kodlar bilimin doğası alanında çalışan başka bir araştırmacı tarafından da kontrol edilmiş ve kodlar üzerinde uzlaşma sağlanmıştır (Creswell, 2007; Lincon ve Gubba, 1985).

Bilimin doğası görüşler anketi analizi (VNOS-C): Katılımcıların bilim doğası görüşleri ile ilgili profillerini oluşturmak için Lederman, Abd-El-khalick, Bell ve Schwartz (2002) tarafından geliştirilen rubrik kullanılmıştır. Analiz yapılırken katılımcıların bilimin doğası ile ilgili görüşleri üç ana kategori altında incelenmiştir. Katılımcıların bilimin doğası ile ilgili görüşleri yetersiz, yeterli ve bilgili olarak üç ana kategori altında incelenmiştir (Akerson ve Abd-El-Khalick, 2009; Akerson, Cullen, ve Hanson, 2009; Lederman, Abd-El-Khalick, Bell, ve Schwartz, 2002). Bu kategorizasyonda yetersiz görüş, bilimin doğası ile ilgili sahip olunan kavram yanılgılarını ifade etmektedir. Örneğin, bilimin değişmez olarak tanımlayan katılımcı yetersiz görüş kategorisine alınmıştır. Yeterli görüş ise bilimin doğası ile ilgili kabul edilebilir görüşleri ifade etmektedir. Fakat bu yeterli görüş kategorisinde sınıflandırılmış bir katılımcı ifade ettiği görüşü detaylı açıklamalar veya örneklerle destekleyememiştir. Örneğin bilimsel bilginin değişebilir olduğunu kabul eden katılımcı bu değişimin nasıl olduğunu açıklayamamış veya örneklerle destekleyememişse görüşü yeterli olarak sınıflandırılmıştır. Bilimin doğası ile ilgili bilgili görüş kategorisi ise katılımcının bilimin doğası ile ilgili kabul edilebilir görüşlere sahip olduğunu ve bu görüşlerini detaylı açıklama veya örneklerle desteklediğini gösterir. Örneğin bilgili görüş kategorisinde sınıflandırılmış görüşteki katılımcı bilimsel bilginin değişebilir olduğunu kabul etmekle beraber bu değişimin var olan verinin yeniden yorumlanmasıyla, bilim insaninin bakış açısındaki değişikler veya yeni veri elde edilmesiyle olacağını da ifade eder. Yeterli görüş ile bilgili görüş arasındaki temel fark, katılımcıların açıklamalarındaki derinlik, açıklamanın detaylandırılması ve örneklerle zenginleştirilmesidir. Aşağıda belirtilen tablo 6. her bir kategoriyi bilimin doğası boyutları ile ilgili olarak özetlemektedir:

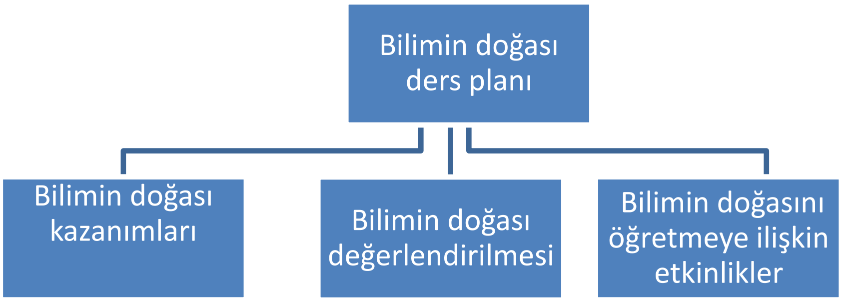
Tablo 6. Bilimin doğası boyutları kategorizasyonu

Kategorizasyon	Yetersiz	Yeterli	Bilgili
Bilimsel bilginin değişebilir yapısı	Bilimsel bilgiyi kesin ve değişemez olarak ifade eder. Kanunları da kesin ve değişemez olarak ifade eder	Bilimsel bilgiyi değişebilir olarak ifade eder. Kanun ve teoriler i değişebilir olarak ifade eder.	Bilimsel bilgi (kanun ve teoriler dahil olmak üzere) bilim insanlarının bakış açısı, elde olan verilerin yeniden yorumlanması, gelişen teknoloji ile elde edilen yeni veriler sayesinde değişir. Görüş ayrıca detaylı açıklama veya örneklerle desteklenmiştir.
Bilimsel bilginin delile dayalı yapısı	Bilimi diğer disiplinlerden delillerin rolünü vurgulayarak ayırt edemez. Bilimsel bilgi elde edilirken delillerin rolünü göz ardı eder. Deneylerin bilimsel bilgiyi birebir ispatladığını savunur.	Bilimin deney ve gözlemler içerdiğini vurgular. Fakat deney ve gözlemlerin bilimsel bilgiyi destekleyen deliller elde etmek için kullanıldığını vurgulayamaz.	Bilimsel iddialar /bilgiler oluşturulurken bu iddia/ bilgilerin deney ve gözlemler sonucu elde edilen verilerin yorumlanmasıyla oluşturulmuş delillerle desteklendiğini ifade eder. Görüş ayrıca detaylı açıklama veya örneklerle desteklenmiştir
Bilimsel bilginin çıkarımsal yapısı	Bilim insanının yaptığı deneyler ve gözlemler sayesinde bilimsel olayları/bilgileri birebir gördüklerini savunur. Bilimde her şeyin beş duyu organıyla gözlemlendiğini savunur. Bilim insanının çıkarım yaptığını göz ardı eder.	Bilim insanının çıkarım yaptığını ima eder. Fakat gözlem ve çıkarım arasındaki farkı belirtmez. Bilim insanının gözlemlere dayalı çıkarım yaptığını belirtmez.	Bilim insanının doğadaki tüm olguları birebir gözlemleyemeyeceğinin farkındadır. Bilim insanlarının gözleme dayalı çıkarımlar yaptığını belirtir. Görüş ayrıca detaylı açıklama veya örneklerle desteklenmiştir.
Bilimde hayal gücü ve yaratıcılık	Bilimi belli bir prosedürü olan bir aktivite olarak görür. Bilimsel aktivitelerde bilim insanının yaratıcılık ve hayal gücünün rolünü göz ardı eder.	Bilim insanın yaratıcılık ve hayal bilimsel bilgi üzerindeki rolünü ifade eder. Fakat bilim insanının yaratıcılık ve hayal gücünü bilimsel sürecin belli basamaklarında kullanıldığına inanır.	Bilim insanının yaratıcılık ve hayal gücünün rolünün bilimsel sürecin her aşamasında etkili olduğunu ifade eder. Görüş ayrıca detaylı açıklama veya örneklerle desteklenmiştir.
Bilimsel bilginin sosyal kültürel yapısı	Bilimi içinde bulunduğu toplumdan soyutlanmış evrensel bir aktivite olarak tanır. Bilim ve toplumun birbirleri üzerinde olan etkisini göz ardı eder.	Bilimin sosyal kültürel değerlerden etkilenen bir aktivite olduğunu ifade eder.	Bilimin ve toplumun sosyal kültürel değerlerinin iki taraflı olarak birbirlerini etkilediğini ifade eder. Görüş ayrıca detaylı açıklama veya örneklerle desteklenmiştir.
Kanun ve teoriler	Kanun ve teori arasında hiyerarşik bir ilişki olduğunu ifade eder.	Kanun ve teorileri farklı bilimsel bilgi türleri olarak tanımlar. Fakat teori ve kanun ile ilgili detaylı açıklamalar yapamaz.	Teori ve kanunları farklı fakat aynı derecede güvenilir bilimsel bilgi olarak ifade eder. Teori ve kanunun ne ifade ettiğini doğru bir biçimde açıklayabilir. Görüş ayrıca detaylı açıklama veya örneklerle desteklenmiştir.
Bilimde öznellik	Bilim insanları objektiftir. Yaptığı iş bilim insanının kişisel inançları, sahip olduğu teorik bakış açısı ve önyargılarından etkilenmez.	Bilim insanının yaptığı işin onun sahip olduğu insanının kişisel inançları, sahip olduğu teorik bakış açısı, ve önyargılarından etkilendiğini ifade eder fakat görüşünü detaylı açıklamalar veya örneklerle destekleyemez.	Bilim insanını sahip olduğu kişisel inançların, teorik bakış açısının, önyargılarının, yaratıcılığının, veri toplama, veriyi yorumlama, araştırma dizayn etme vb. Gibi birçok bilimsel süreci etkilediğini ifade eder. Görüş ayrıca detaylı açıklama veya örneklerle desteklenmiştir

Yarı yapılandırılmış görüşme ve yansıtıcı rapor analizi: Yarı-yapılandırılmış görüşmeler ve yansıtıcı raporlar katılımcıların bilimin doğası öğretimine yönelik görüşlerini araştırmak için nitel veri analiz yöntemlerine göre analiz edilmiştir. Bu amaçla katılımcıların görüşme sorularına verdikleri cevaplar tekrar tekrar okunmuş ve görülen kategori ve kodlar çıkarılmıştır (Creswell, 2007; Merriam, 2009)

Ders planı analizleri:

Ders planları katılımcıların bilimin doğasına yönelik ders dizayn etme becerilerini göstermektedir. Katılımcıların bu becerilerindeki gelişimine literatür ve uzman görüşünden faydalanılarak bir bilimin doğası ders planı değerlendirme anahtarı oluşturularak karar verilmiştir. Uzman görüşünden faydalanılarak katılımcılardan hazırlamaları istenen bilimin doğası ders planlarının üç ana kısımdan oluşması öngörülmüştür. Buna göre bu çalışmada bilimin doğasına ilişkin ders planı yazılan bilimin doğası ile ilgili kazanımlara bilimin doğasını açık yansıtıcı bir biçimde vurgulayan etkinliklere ve bilimin doğasının ders planının değerlendirme kısmına dâhil edilip edilmemesine göre incelenmiştir. Aşağıdaki şekil 1 de de özetlenen bilimin doğası ders planı kısımları göz önüne alınarak ders planı değerlendirme rubriği oluşturulmuştur.



Şekil 7. Bilimin doğası ders planı kısımları

Buna göre ders planını 3 kısımdan oluştuğu düşünülmüş ve her bir kısım kendi içinde bilimin doğasını entegre etmesi açısından değerlendirilmiştir. Değerlendirme yapılırken her kişi için üç kategori oluşturulmuş ve katılımcıların bu üç kısımdaki gelişmeleri rapor edilerek genel gelişmeleri özetlenmiştir. Buna göre ders planı kazanımlar kısmı, etkinlikler kısmı ve değerlendirme kısmı olarak üç ana kısım belirlenerek bilimin doğası entegrasyonu açısından üç kategori altında değerlendirilmiştir. Kategoriler uzman görüşü ve literatürden faydalanılarak oluşturulmuştur. Bu kategoriler, yetersiz açık ve yansıtıcı bilimin doğası planlaması, kısmen yeterli açık ve yansıtıcı bilimin doğası planlaması ve yeterli bilimin doğası planlaması olmak üzere oluşturulmuştur. Ders planının her bir kısmı için kategorilerin ayrıntılı açıklaması aşağıdaki gibidir:

Kazanımlar: Der planında yazılan bilimin doğası ile ilgili kazanımlar aşağıda açıklanan üç kategori altında sınıflandırılmıştır:

Yetersiz: Bilimin doğası ile ilgili olarak kazanım yazılmamış olmasını ifade eder.

Kısmen yeterli: Bilimin doğası ile ilgili olarak doğrudan yazılan bir kazanım olmasa da, bilimin doğasını yapılan planlamaya dâhil etmeye yönelik bir niyet söz konusudur. Yazılan kazanım doğrudan bilimin doğası ile alakalı değildir fakat ders planı içerisindeki etkinlikler incelendiğinde, yazılan kazanımın bilimin doğası ile ilgili bilgi beceri kazandırmaya çalıştığı anlaşılır. Örneğin, katılımcının yazdığı "öğrenci atom modellerinin zamanla değiştiğini açıklayabilir" gibi bir kazanım yazıp, ders planının etkinlikler kısmında da bilimin değişebilir doğasına yer veriyorsa, araştırmacı, katılımcının bilimin doğasını ders planına dahil etmeye ve bu amacını da kazanımlarda göstermeye niyeti olduğuna karar vermiştir. Bu nedenle bilimin doğası ile ilgili olarak yazılan bu kazanım kısmen yeterli olarak kabul edilmiştir.

Yeterli: Bu kategoride kabul edilen kazanım doğrudan bilimin doğasını öğretmeye yönelik bir niyet olduğunu gösterir. Yazılan kazanım doğrudan bilimin doğası ile alakalıdır. Örneğin, "öğrenciler bilimsel bilginin değişebilir olduğunu açıklar" gibi bir kazanım doğrudan bilimsel bilginin değişebilir doğası ile ilgilidir ve yeterli olarak kabul edilir.

Etkinlikler: Ders planında yazılan bilimin doğası ile ilgili etkinlikler aşağıda açıklanan üç kategori altında sınıflandırılmıştır:

Yetersiz: Bu kategori, ders planında kazanımların sağlanması için yapılan her türlü etkinliği içerir. Eğer katılımcı bilimin doğasını açık ve yansıtıcı bir biçimde anlatmak için bir çaba göstermemişse, katılımcının bu planı bu kısım için yetersiz olarak sınıflandırılmıştır.

Kısmen yeterli: Açık ve yansıtıcı yaklaşım, birbirinden ayrılmayan bütün bir yaklaşımdır. Yani bilimin doğasını anlatmaya yönelik herhangi bir girişim hem açık hem de yansıtıcı olmalıdır. Bu iki özellik birbiri için gerekli ve birbirini tamamlayan özelliklerdir (Abd-El-Khalick, 2005). Bu bağlamda bilim doğası ile ilgili herhangi bir kazanıma sahip olup, bu kazanımın elde edilmesine yönelik bir etkinlik sağlanmaması veya bilimin doğasına yönelik etkinlikler sağlayıp bunu kazanımlarda belirtmemek yapılan bilimin doğasına yönelik öğretimin etkinliğini azaltır ve öğrencilerin bilimin doğasına yönelik gelişimlerine bir katkıda bulunmaz (Abd-El-Khalick, 2005). Bu nedenle eğer bilimin doğasına yönelik kazanım ve etkinlikler arasında bir tutarsızlık varsa bu planlama kısmen yetersiz olarak sınıflandırılmıştır. Buna ek olarak, eğer katılımcı bilimin doğasını sadede doğrudan anlatımla öğretmeyi planladıysa, öğretimin yansıtıcı yanının olmaması sebebiyle, gene planı etkinlik kısmı için kısmen yeterli olarak sınıflandırılmıştır.

Yeterli: Bu sınıflandırma öncelikle ders planında bilimin doğasına yönelik kazanım ve etkinlik arasında bir tutarlılık olduğunu göstermektedir. Buna ek olarak ders planında bilimin doğasını vurgulamaya yönelik sorular, tartışma durumları, örnekler sağlanmıştır. Ayrıca, bilimin doğası ile içerik arsındaki ilişkilendirilme ders planında başarılı olarak yapılmıştır.

Değerlendirme: Ders planında yazılan bilimin doğasına yönelik değerlendirme iki kategori altında sınıflandırılmıştır.

Yetersiz: Ders planında bilimin doğasına yönelik herhangi bir değerlendirme olmadığını göstermektedir

Yeterli: ders planında bilimin doğası ile ilgili kazanımların kazanılıp kazanılmadığına dair bir ölçme yapıldığını göstermektedir.

BULGULAR

Bilimin doğasına ait görüşlerde değişimler:

Yapılan analizler sonucu, katılımcıların bilimin doğası ile ilgili görüşlerinde önemli ilerlemeler kaydettikleri görülmüştür. Yapılan uygulama sonucunda katılımcıların hepsi görülerini, yeterli veya bilgili görüş kategorisine geliştirmiş, hiçbir katılımcının herhangi bir bilimin doğası boyutunda yetersiz görüşe sahip olmadığı gözlenmiştir. Bilimin doğası boyutları arasında en çok gelişimi katılımcılar, teori ve kanun boyutu ile bilimin sosyal kültürel yapısı boyutunda göstermiştir. Buna göre, uygulama öncesinde katılımcıların hepsi, teori ve kanunlar arasında hiyerarşik bir yapı olduğunu düşünüyorken, uygulama sonrasında bütün katılımcılar teori ve kanunun farklı bilimsel bilgi olduğu, birbiri arasında hiyerarşik bir yapı olmadığı, teorilerin bilimsel olguları açıklarken kanunların gözlemlenen bilimsel olguları ifade ettiği anlayışını geliştirmiştir. Kısaca, uygulama sonunda tüm katılımcılar teori ve kanun ile ilgili olarak bilgili görüş sergilemiştir. Aynı şekilde, uygulama öncesinde, tüm katılımcılar bilimi evrensel olarak tanımlarken, uygulama sonrasında bilimin sosyal kültürel yapısı ile ilgili olarak bilgili görüşe sahip olmuşlardır. Benzer olarak, uygulama başlangıcında altı kişi bilimde öznellik ve bilimsel bilginin değişebilir doğası ile ilgili yetersiz görüşe sahipken, uygulama sonrasında tüm katılımcılar bu boyutlarla ilgili olarak bilgili görüş ortaya koymuştur. Uygulama başlangıcında bilimsel bilginin delile dayalı yapısı ile ilgili olarak yetersiz görüşe sahip katılımcılardan beş kişi bu görüşlerini bilgili olarak iki kişi ise yeterli görüş olarak geliştirmiştir. Bilimsel bilgide yaratıcılık ve hayal gücü ile ilgili olarak, uygulama başlangıcında üç kişi yeterli görüşe sahipken dört kişi yetersiz görüşe sahiptir. Uygulama sonrasında ise tüm katılımcılar bu boyutla ilgili olarak görüşlerini bilgili görüş olarak geliştirmiştir. Bilimin çıkarımsal yapısı ile ilgili olarak uygulama başlangıcında katılımcıların yaklaşık yarısının yeterli görüşe sahip olduğu görülmüştür. Uygulama sonrasında ise, altı katılımcı bilgili görüş sergilerken, başlangıçta yetersiz görüşe sahip bir katılımcı görüşünü yeterli görüşe doğru geliştirmiştir.

Bilimin doğasına yönelik ders planlarındaki gelişim:

Genel olarak katılımcıların hepsi bilim doğası entegre edilmiş ders planlarında gelişim göstermiş ve bilimin doğasını açık ve yansıtıcı bir biçimde planlayabilmiştir. Başlangıçtaki ders planlarında, katılımcılar bilimin doğası ile ilgili kazanım yazmakta ve bu kazanımları etkinlikler aracılığıyla yansıtmakta zorluk çekmişlerdir. Fakat son ders planları göstermiştir ki uygulama süresince katılımcılara verilen geri-dönüt, bilim tarihinden sağlanan örnekler, ders planlarının mikro öğretim yoluyla sunulması, katılımcıların gelişimine önemli katkılar yapmıştır. Buna göre katılımcılar uygulama sonrasında birçok boyut için açık ve yansıtıcı olarak planlama yapabilmişlerdir. Katılımcılar, çoğunlukla bilimsel bilginin delile dayalı yapısını açık ve yansıtıcı bir biçimde planlayabilmişlerdir. Bu boyutu bilimsel bilginin değişebilir yapısı ve bilimsel öznellik boyutları izlemiştir. Buna göre altı kişi bilimsel bilginin delile dayalı yapısını açık ve yansıtıcı bir biçimde planlayabilirken, beş kişi bilimsel bilginin değişebilir yapısını açık ve yansıtıcı bir biçimde planlayabilmiştir. Katılımcılardan dört kişi bilimde öznellik boyutunu açık ve yansıtıcı bir biçimde planlayabilmiş, fakat sadece birer kişi bilimde yaratıcılık ve hayal gücü ile teori kanun boyutlarını açık ve yansıtıcı bir biçimde planlayabilmişlerdir.

Katılımcılar, bilimin doğasına yönelik ders planı hazırlama becerilerindeki gelişimin çoğunlukla ders planlarını mikro-öğretim ile sunma ve bunu takip eden tartışma etkinliklerinden kaynaklandığını ifade etmişlerdir. Katılımcılardan üçü ise kendilerindeki bilimin doğasına yönelik ders dizayn etme becerilerinin gelişimine araştırmacıdan ders planlarına yönelik aldıkları geri-dönütün önemli katkısı olduğunu ifade etmiştir.

Sonuç olarak, bu uygulamada kullanılan farklı öğrenme ortamlarıyla ilişkilendirilmiş açık yansıtıcı bilimin doğası yaklaşımının, geri-dönüt, yansıtıcı etkinlikler, mikro-öğretim, ders planı hazırlama gibi etkinliklerle zenginleştirilmesiyle etkinliği artmış ve katılımcıların bilimin doğası görüşlerinin gelişimi ve bilimin doğası ile ilgili ders dizayn etme becerilerine olumlu katkıları olmuştur.

APPENDIX E

CURRICULUM VITAE

PERSONAL DETAILS

Address : ODTU Egitim Fakultesi, MODSİMER

06531 Cankaya, Ankara, TURKEY

Phone : (090) 312 210 7382

E-mail : bkader@metu.edu.tr

Education:

Phd 2006 -

Middle East Technical University (METU)

Education Faculty

Elementary Science Education

Bachelour 2001 - 2006

Middle East Technical University (METU)

Education Faculty

Elementary Science Education

GPA: 3.18

Current Position:

Research assistant	2006 -
Middle East Technical University (METU)	
Education Faculty	
Elementary Science Education	

Research Related Activities

	2010 - 2011
Visiting scholar Indiana University	
School of Education	
Bloomington, IN, ABD	
Exchange student program Ghent University	2009 - 2010
School of Education	
Ghent, Belgium	

Workshops

European Educational Research Summer School: Writing Educational Research Gothenburg,	2011

Sweeden

European Science Education 2008
Research Association

Science Learning Centre University of York

York, UK

Projects:

2011

Research Associate -Developing pre service science teachers' self effciacy beliefs regarding nature of science teaching .Funded by METU (2011).

Responsibilities included: framing science method course and improving class activities to improve pre service science teachers self-efficacy beliefs regarding teaching nature of science, data collection and analysis of the project data, presenting reserach findings at proffessional conferences

2010

Research Associate- Fall Saturday Science Program, Indiana University, IN. Responsibilities included: Data collection and analysis of the project data, writing manuscript of the research

Research Associate- Exploring elementary science methods course contexts for improving nature of science conceptions and understanding of NOS, Indiana University, IN.

Responsibilities included: Field observation, data collection and assiting Dr. Valarie Akerson for writing "Exploring elementary science methods course contexts for improving nature of science conceptions and understanding of NOS" research paper.

2009

Research Associate: Exploring pre service science teachers nature of concepts and integration of nature of science concepts in lesson plans. Funded by METU. Responsibilities included: Data collection and analysis of the project data, writing manuscript of the research

2008

Research Associate: İlköğretim Fen ve Teknoloji Dersi Öğretmenlerinin Bilimin Doğası Hakkındaki Bilgi ve İnanışlarının Geliştirilmesi ve Sınıf İçi Uygulamalarının İncelenmesi, (2008). Destekli Arastirma Projesi, Kurum: TÜBİTAK , Süre : 12 Ay

Responsibilities included: Data collection and analysis of the project data, writing manuscript of the research.

Invited Talks:

İlköğretim Fen ve Teknoloji Dersi Öğretmenlerine "Bilimin Doğası Semineri", MEB, 16-20.06.2008, Akçakoca, DÜZCE

Books / Publications / Presentations:

Aydeniz, M., & Bilican, K. (2014). What do scientists know about the nature of science? A case study of novice scientists'views of nos. *International Journal of Science and Mathematics Education*, 1-33.

Dogan, N., Cakiroglu, J., Bilican, K., & Cavus, S. (2013). What Nos Teaching Practices Tell Us: A Case Of Two Science Teachers. *Journal of Baltic Science Education*, *12*(4).

Bilican, K., Tekkaya, C., & Cakiroglu, J. (2012). Pre-service science teachers' instructional planning for teaching nature of science: a multiple case study.*Procedia-Social and Behavioral Sciences*, *31*, 468-472.

Cakiroglu, J., Dogan, N., Cavus, S., **Bilican, K**., Arslan, O. (2011). Developing science teachers' nature of science views: The effect of in service teacher education program.

Hacettepe University Journal of Education, 40, 127-139.

Doğan, N., Çakıroğlu, J., **Bilican, K.,** Çavuş, S. (2009). Nature of Science and Nature of Science teaching. Ankara: Pagem A Publications.

Cakiroglu, J., Dogan, N., **Bilican, K**., Cavus, S., Arslan, O. (2009). Influence of in-service teacher education program on science teachers' views of nature of science. *The International Journal of Learning. 16 (10),* 597-606.

Akerson, V., Weiland, I., **Bilican, K**., Pongsanon, K. & Park Rogers, M. (2012). Exploring elementary science methods course contexts for improving nature of science conceptions and understanding of NOS. Paper presented at the meeting of National Association for Research in Science Teaching (NARST), Inadianapolis, IN, USA, 25-28 March.

Bilican, K., Cakiroglu, J. (2012). Investigating use of self efficacy sources in improving pre service science teachers' self efficacy beliefs regarding teaching nature of science . Paper presented at the meeting of National Association for Research in Science Teaching (NARST), Inadianapolis, IN, USA, 25-28 March.

Ozdem, Y., **Bilican, K**. (2012). A case study of a pre service science teachers nature of science teaching and argumentation. Paper presented at the meeting of National Association for Research in Science Teaching (NARST), Inadianapolis, IN, USA, 25-28 March.

Bilican, K., Tekkaya, C., & Cakiroglu, J. (2011). Pre-Service science teachers' instructional planning for teaching nature of science: A multiple case study. Paper presented at world Conference on Learning, Teaching and Administration, Istanbul, Turkey, 28-30 October.

Bilican, K., & Cakiroglu, J. (2011). A case study on pre-service science teachers' self-efficacy beliefs on teaching nature of science. Paper presented at the meeting of The European Conference on Educational Research (ECER),Berlin, Germany, 13-16 September.

Bilican, K., & Ozdem, Y**.** (2011). Analysis of pre-service science teachers' understanding of NOS and warrants on socio-scientific issues. Poster presented at the meeting of National Association for Research in Science Teaching (NARST), Orlando, FL, USA, 3-6 April.

Bilican, K., Ozdem, Y. & Tekkaya, C. (2010). A qualitative study of pre-service science teachers' understanding of nature of science and their approaches to science teaching. Paper presented at XIV. International Organization for Science and Technology Education

Symposium (IOSTE), Slovenya, 13-18 June.

Tekkaya, C., **Bilican, K.,** & Ozdem, Y**.** (2009). A case study on pre-service teachers' understanding of NOS and related pedagogical content knowledge. Paper presented at, European Science Education Research Association Conference, İstanbul, Türkiye, 31 August-4 September.

Dogan, N., Cakiroglu, J., **Bilican, K.,** Cavus, S., Arslan, O. (2009). Developing nature of science views of Turkish science teachers through professional development program. Paper presented at European Science Education Research Association (ESERA), Istanbul August 31st - September 4th .

Cakiroglu, J., Dogan, N., Cavus, S., **Bilican, K.,** Arslan, O. (2009). Influence of in-service teacher education program on science teachers' views of the nature of science.Paper presented at The Sixteenth International Conference on Learning University of Barcelona, Spain, 1-4 July.

Bilican, K., Cakiroglu, J., & Tekkaya, C. (2009). A case study of preservice science teachers' feelings about teaching the nature of science. Paper presented at The Sixteenth International Conference on Learning University of Barcelona, Spain, 1-4 July.

Arslan, H., Cigdemoglu, C., & **Bilican, K**. (2008). An analysis of new science and technology program in the context of environmental education. Paper presented at XIII. International Organization for Science and Technology Education Symposium (IOSTE), (IOSTE), Izmir, Turkey, 21-26 September.

Bilican, K., Cakıroglu,J. & Tekkaya, C. (2008). The influence of explicit reflective instruction of nature of science on Turkish prospective science teachers' understanding of nature of science through 5-E learning cycle. Paper presented at Conference of Asian Science Education, 20-23 February, Kaohsiung, Taiwan.

Teaching Experience (Teaching Assistant):

Methods of Teaching Science

Laboratory Applications in Science Teaching I-II

Awards

2012 NARST International Committee Scholarship

2011 European Educational Research Summer School Travel Award

2008 ESERA Summer School Travel Award

Membership in proffesional organizations

National Association for Research in Science Teaching (NARST)

European Science Education Research Association (ESERA)

Turkish Science Education and Research Association (FEAD)

TEZ FOTOKOPİSİ İZİN FORMU

ENSTİTÜ

Fen Bilimleri Enstitüsü	☐
Sosyal Bilimler Enstitüsü	■
Uygulamalı Matematik Enstitüsü	☐
Enformatik Enstitüsü	☐
Deniz Bilimleri Enstitüsü	☐

YAZARIN

Soyadı : Bilican
Adı : Kader
Bölümü : İlköğretim

TEZİN ADI (İngilizce) : DEVELOPMENT OF PRE-SERVICE SCIENCE TEACHERS NATURE OF SCIENCE VIEWS AND NATURE OF SCIENCE INSTRUCTIONAL PLANNING WITIHIN A CONTEXTUALZIED EXPLICIT REFLECTIVE APPROACH

TEZİN TÜRÜ : Yüksek Lisans ☐ Doktora ■

1. Tezimin tamamından kaynak gösterilmek şartıyla fotokopi alınabilir. ☐
2. Tezimin içindekiler sayfası, özet, indeks sayfalarından ve/veya bir bölümünden kaynak gösterilmek şartıyla fotokopi alınabilir. ☐
3. Tezimden bir bir (1) yıl süreyle fotokopi alınamaz. ■

TEZİN KÜTÜPHANEYE TESLİM TARİHİ: