DEVELOPMENT OF PRE-SERVICE CHEMISTRY TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE FOR NATURE OF SCIENCE: AN INTERVENTION STUDY

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DEVELOPMENT OF PRE-SERVICE CHEMISTRY TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE FOR NATURE OF SCIENCE: AN INTERVENTION STUDY

submitted by **BETÜL DEMİRDÖĞEN** in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Secondary Science and Mathematics Education Department, Middle East Technical University** by,

Prof. Dr. Canan Özgen ____________
Dean, Graduate School of **Natural and Applied Sciences**

Prof. Dr. Ömer Geban ____________
Head of Department, **Secondary Science and Math. Edu.**

Assoc. Prof. Dr. Esen Uzuntiryaki Kondakçı ____________
Supervisor, **Secondary Science and Math. Edu. Dept., METU**

Prof. Dr. Fitnat Köseoğlu ____________
Co-Supervisor, **Secondary Science and Math. Edu. Dept., Gazi U.**

Examining Committee Members:

Prof. Dr. Jale Çakıroğlu ____________
Elementary Education Dept., METU

Assoc. Prof. Dr. Esen Uzuntiryaki Kondakçı ____________
Secondary Science and Math. Edu. Dept., METU

Prof. Dr. Ömer Geban ____________
Secondary Science and Math. Edu. Dept., METU

Assoc. Prof. Dr. Deborah L. Hanuscin ____________
Learning, Teaching, and Curriculum Dept.
University of Missouri, USA

Assoc. Prof. Dr. Yezdan Boz ____________
Secondary Science and Math. Edu. Dept., METU

Date: 20.11.2012

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name:

Signature :

ABSTRACT

DEVELOPMENT OF PRE-SERVICE CHEMISTRY TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE FOR NATURE OF SCIENCE: AN INTERVENTION STUDY

Demirdöğen, Betül
Ph.D., Department of Secondary Science and Mathematics Education
Supervisor: Assoc. Prof. Dr. Esen Uzuntiryaki Kondakçı
Co-Supervisor: Prof. Dr. Fitnat Köseoğlu

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The purpose of this study was to delve into the complexities of development of preservice chemistry teachers' science teaching orientation, knowledge of learner, knowledge of instructional strategies, and knowledge of assessment during Pedagogical Content Knowledge (PCK) for Nature of Science (NOS) instruction. Thirty pre-service chemistry teachers enrolled Research in Science Education course participated to the study. Case study, one of the qualitative research methods, was used as research design. PCK for NOS instruction spanned two semester weeks including learning NOS, explicit-reflective, and learning how to teach NOS, addressed four PCK components, parts. This study only involved the collection of qualitative data sources including responses given to an open ended instrument, interviews, observations, and documents such as lesson plans and reflection papers. In-depth analysis of explicit PCK and constant comparative method were used as data analysis methods. Results revealed that most of the pre-service chemistry teachers had naive and transitional views about NOS. However, they had informed view after explicit-reflective NOS instruction. Although all participants developed PCK for NOS in some extent and nevertheless the participants' PCK for NOS were different from each other in terms of both the degree of integration among the components and the degree to which these components and connections manifest themselves in their lesson plans and reflection papers. Moreover, there was no clear relationship between the participants' NOS understandings and their PCK for NOS whereas most of them attempted to teach NOS aspects that they had informed views.

Keywords: Pedagogical Content Knowledge, Nature of Science, Science Teacher Education, Case Study

ÖZ

KİMYA ÖĞRETMEN ADAYLARININ BİLİMİN DOĞASI KONUSUNDA PEDAGOJİK ALAN BİLGİLERİNİN GELİŞİMİ: BİR UYGULAMA ÇALIŞMASI

Demirdöğen, Betül
Doktora, Orta Öğretim Fen ve Matematik Alanları Eğitimi Bölümü
Tez Yöneticisi: Doç. Dr. Esen Uzuntiryaki Kondakçı
Ortak Tez Yöneticisi: Prof. Dr. Fitnat Köseoğlu

Kasım, 2012, 368 sayfa

Bu çalışmanın amacı bilimin doğası için pedagojik alan bilgisi (PAB) öğretim sürecinde kimya öğretmen adaylarının fen öğretimi amaçlarını, öğrenci anlayışları ile ilgili bilgilerini, öğretim stratejileri bilgilerini ve değerlendirme bilgilerinin gelişimini incelemektir. Kimya Öğretiminde Araştırmalar dersini almakta olan 30 kimya öğretmen adayı çalışmaya katılmıştır. Nitel araştırma metodlarından biri olan durum çalışması araştırma desenini oluşturmuştur. Bilimin doğasını öğrenme ve bilimin doğasını nasıl öğreteceğini öğrenme bölümlerinden oluşan bilimin doğası için PAB öğretim süreci iki öğretim dönemi boyunca sürmüştür. Çalışmanın veri kaynaklarını açık-uçlu sorulara verilen cevaplar, görüşmeler, gözlemler ve ders planları oluşturmuştur. Verilerin analizinde derinelemesine PAB ve sürekli kaşılaştırmalı veri analiz yöntemleri olarak kullanılmıştır. Çalışmanın sonuçları bilimin doğası öğretiminden önce kimya öğretmen adaylarının bilimin doğası ile ilgili çeşitli yanlış inanışlara sahip olduklarını ve açık-düşündürücü yaklaşımla yürütülen bilimin doğası öğretiminden sonra bu inanışların yerini yeterli anlayışlara bıraktığını göstermiştir. Ayrıca, öğretmen adaylarının tümü belirli bir düzeyde bilimin doğası için PAB bilgisine sahip olmakla birlikte PAB bileşenleri arasında ne derece bağlantı kurdukları ve bu bileşenleri ve bağlantıları ders planlarına ve yansıtma yazılarına ne derece aktardıkları bakımından farklılık göstermişleridir. Daha da önemlisi, öğretmen adaylarının bilimin doğası anlayışları ve PAB'ları arasında açık bir ilişki bulunmamıştır. Bununla birlikte, kimya öğretmen adayları yeterli anlayışa sahip oldukları bilimin doğası boyutlarını öğretmeyi tercih etmişlerdir.

Anahtar Kelimeler: Pedagojik Alan Bilgisi, Bilimin Doğası, Fen Öğretmen Eğitimi, Örnek Olay Çalışması

To myself, to the most beautiful years of my life, and to my family

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TABLE of CONTENTS

LIST OF FIGURES

FIGURES

LIST OF TABLES

TABLES

LIST OF ABBREVIATIONS

SL: Scientific Literacy

NOS: Nature of Science

AAAS: American Association for the Advancement of Science

NRC: National Research Council

STS: Science-technology-society

MoNE: Ministry of National Education

PCK: Pedagogical Content Knowledge

PK: Pedagogical Knowledge

SMK: Subject Matter Knowledge

STO: Science Teaching Orientation

KoL: Knowledge of Learner

KoIS: Knowledge of Instructional Strategy

KoC: Knowledge of Curriculum

KoA: Knowledge of Assessment

PSA: Philosophy of Science Association

VOSTS: Views on Science-Technology-Society

NSTQ: Nature of Science and Technology Questionnaire

VNOS: Views of Nature of Science

VNOS-C: Views on Nature of Science Form-C

VNOS-B: The Views of Nature of Science Form B

LCQ: Learning Context Questionnaire

SVI: Schwartz Values Inventory

KoCx: Knowledge of Context

PCKg: Pedagogical Content Knowing

TUBITAK: The Scientific and Technological Research Council of Turkey

ESA: Expected Student Answer

HI-A: Highly-Integrated in Application level

HI-KA: Highly-Integrated in Knowledge-Application level

HI-K: Highly-Integrated in Knowledge level

SI-A: Somewhat-Integrated in Application level

SI-KA: Somewhat-Integrated in Knowledge-Application level

SI-K: Somewhat-Integrated in Knowledge level

NI-A: Non-Integrated in Application level

CoRe: Content Representation

PaP-eRs: Professional and Pedagogical experience Repertoire

SSME: Secondary Science and Mathematics Education

NARST: National Association for Research in Science Teaching

USA: United States

IRB: Institutional Review Board

R: Researcher

CHAPTER I

INTRODUCTION

"Why do medical doctors change their ideas and disagree with eachothers?"

Seyhan, A housewife lady, Personal communication [15.12.2011]

This was the reaction of Seyhan to the dispute among medical doctors on whether individuals with high cholesterol level in their blood should take medication or not. On a TV programme, some of the medical doctors were advocating the inefficacy of medication against cholesterol while some others were strongly recommending medication to the patients with high cholesterol level. She was surprised and could not able to realize why scientists changed their minds and did not reach a consensus. On the other hand, I was not shocked as much as she was. Why did we differ in terms of our reactions? The answer was lying under the difference of our understanding about what science is and how it works, that is nature of science (NOS). I, as an individual with adequate understanding of NOS, was aware of tentativeness of scientific knowledge and the role of subjectivity in science and therefore, understand the underlying reasons for the change in scientists' ideas and dispute among them. This knowledge on NOS puts me on a higher position than Seyhan in terms of our scientific literacy (SL) levels.

SL has been a slogan among science educators and set as an important goal for science education community by reform documents (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996) and curriculums in different countires such as Turkey, Britain, Netherlands, North America, Canada, Australia, and South Africa (Dillon, 2009). Why it is important to achieve SL and how this contributes to individual and society are another important points that need consideration. Several researchers provided various arguments for this issue. For instance, DeBoer (2000), in his analysis of historical and contemporary meanings of SL, stated that SL defines what the public should know about science in order to live more effectively in the natural world instead of identifying what individuals should learn about science to be prepared for their science and technology related careers. On the other hand, Laugksch (2000) grouped the arguments for promoting SL as macro and micro view. The macro view includes the benefits to the nation, science, or society. According to macro view, only nations whose citizens have an appropriate level SL will be able to fulfill the need for scientists, engineers, and technically trained personnel required for foundation of research. Moreover, these research programs directly influence the nation's competing on international markets and in turn wealth. Also, higher levels of SL results in greater support for science since the more the public understands about the objectives, processes, and capabilities of science, the less the public will have unrealistic expectations and this will not result in loss of confidence in science and withdrawal of support. On the other hand, micro view deals with the benefits of SL to individual. Micro view suggests that improved understanding of science and technology is advantageous to an individual living in a science and technology dominated society. Personal decisions (e.g., diet, smoking, and vaccination), demarcation of science from other disciplines for being skeptical about pseudo-science (e.g., astrology), and employment for jobs requiring understandings and skills of science and technology are three context where individuals can benefit from SL.

After providing arguments for why SL is important and since this goal shapes the science education, first of all, one should clearly define what SL is. SL is defined as "…the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (NRC, 1996, p. 22).

Besides the definition of SL, the characteristics of a scientifically literate person were listed by NRC document as;

- Ask, find, or determine answer to questions from curiosity about everyday experiences,
- Be able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions,
- Be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it,

- Has the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately.

In addition, DeBoer (2000) provided a long list for characteristics of a scientifically literate person. Some of these caharacteristics are as; differentiating theory from dogma; understanding how scientific research is done and findings are validated; using knowledge of science where appropriate in making decisions, creating judgments, resolving problems, and taking action; distinguishing science from pseudo-science such as astrology; recognizing that science concepts, laws, and theories are tentative; and discriminating evidence from propaganda, fact from fiction, sense from nonsense, and knowledge from opinion.

Although there are several definitions of SL and lists of the characteristics for a scientifically literate individual, there are some agreed upon ingredients of SL as understanding of basic science concepts, NOS, and science-technology-society (STS) relationship (Bauer, 1995; Layton et al., 1994; Shamos, 1995). In this sense, educating for SL not only involves teaching science concepts but also teaching about the NOS (Eichinger, Abell, & Dagher, 1997). Therefore, NOS has been the focus of attention in science education circles as a primary component of SL (Bell & Lederman, 2003).

In line with the science education reform movements around the world and in Turkey, Elementary Science and Technology Education Program determined its' vision as "all students, regardless of individual and cultural differences, should develop scientific and technological literacy" (Ministry of National Education [MoNE], 2000, p. 9). Moreover, having an adequate understanding about how science itself works has been the focus of Secondary Chemistry Education Program (MoNE, 2007, p. 9). The program emphasized that students should not only acquire knowledge and skills of chemistry but also should use scientific methods through internalizing the method itself and gain attitudes, values, and habits seemly to scientists. As NOS has come to be prominence as a component of SL, what the science education community means by NOS should be clearly articulated. According to McComas, Clough, and Almazroa (1998) NOS is;

> ...a fertile hybrid arena which blends aspects of various social studies of science including the history, sociology, and philosophy of science combined

> with research from the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors (p. 4).

Despite what should students learn about NOS has been an important questions among science educators, there is a remarkable consensus on fundamental NOS elements to be communicated to pre-college students (McComas & Olson, 1998; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003; Smith, Lederman, Bell, McComas, & Clough (1997). The aspects which are accessible to K–12 students and constitute contemporary views of NOS are: scientific knowledge is tentative; empirical; theory-laden; partly the product of human inference, imagination, and creativity; and socially and culturally embedded. Three additional important aspects are the distinction between observation and inference, the lack of a universal method for doing science, and the functions of and relationships between scientific theories and laws (Lederman, 2007).

There is a growing body of research on identifying students' views of NOS in several levels of education, from primary school level to university level and by using different instruments. One of the earlier studies to determine the students' conceptions about NOS was conducted by Wilson in 1954 (as cited in Lederman, 1992). This study was primarily an attempt to validate the Science Attitude Questionnaire. Results indicated that students believed that scientific knowledge was absolute and scientists' primary goal was to uncover natural laws and truths. After the work of Wilson, there have been several attemps to reveal students' conceptions in different levels of education. Lederman (1992) was the first who reviewed the studies conducted between 1954-1991 in order to clarify what has been learned about NOS by students and teachers. He concluded that students did not have informed understanding of NOS irrespective from the instruments used to assess understandings. After 1990s, researchers continued investigating students' conceptions of NOS. The majority of these studies focusing on elementary school (Kang, Scharman & Noh, 2005), middle school (Songer & Linn, 1991), high school (Moss, Abrams, & Robb, 2001), and college levels (Ryder & Leach, 1999) showed that students in all levels had naive conceptions regarding NOS. In Turkey, there have been increasing number of studies conducted using different instruments on views of NOS with elementary students (Akçay, 2011; Çelikdemir, 2006; Çetinkaya, Sarıaydın, Kütükçü, & Akçay, 2010; Özdem, Çavaş, Çavas¸ Çakıroğlu, & Ertepınar, 2010; Özkal, Tekkaya, Sungur, Çakıroğlu, & Çakıroğlu, 2011) and secondary students (Akçay, 2011; Bektaş & Geban, 2010; Doğan & Abd- El- Khalick, 2008; Doğan Bora, Arslan, & Çakıroğlu, 2006; Kılıç, Sungur, Çakıroğlu, & Tekkaya, 2005; Şahin & Köksal, 2010). In general, these studies indicated that regardless of the grade level and gender relatively low number of the elementary and high school students had adeqaute views on the some aspects of the NOS.

Attempts to increase students' indequate understanding of NOS, mostly, use one of the two approaches that are implicit and explicit to NOS instruction. Abd-El-Khalick and Lederman (2000) differentiated between implicit and explicit approaches to NOS instruction. In implicit NOS instruction, students engage in science-based activities, but NOS issues are not particularly addressed. It is assumed that students can learn the NOS by doing science. Explicit instruction provides extensive opportunities for students to reflect on their understandings of the NOS and how the readings, lectures, or other learning activities impact their understandings. The weight of the available evidence from numerous studies that employed either of the approaches favors explicit-reflective NOS instruction over implicit one for developing NOS understanding (Abd-El-Khalick & Lederman, 2000).

Who is responsible for students' inadequate understandings about NOS? Teachers are the most influential factor in classroom learning and even well-designed NOS instruction that is incompatible with the teachers' views about science may be ineffective (McComas et al., 1998). Research has consistently shown that teachers' views are not compatible with the contemporary conceptions of NOS (Abd-El-Khalick, Bell, & Lederman, 1998; Akerson, Buzzelli, & Donnelly, 2008; Brown, Luft, Roehrig, & Kern, 2006; Doğan, 2005; Liang, Chen, Chen, Kaya, Adams, Macklin, & Ebenezer, 2008; Liu & Lederman, 2007; Lederman, 1992; Thye & Kwen; 2003; Yakmaci, 1998; Yalvac & Crawford, 2002; Yalvaç, Tekkaya, Çakıroğlu, & Kahyaoğlu, 2007) and therefore teachers have difficulty with teaching an appropriate view to students (Abell & Smith, 1994; Akerson, Abd-El- Khalick, & Lederman, 2000; Lederman, 1992).

Assuming that there is a clear-cut relationship between teachers' understanding of NOS and translation of their NOS understanding into classroom practice, science educators made several attempts for teaching NOS to both pre-service and in-service teachers (Abd-El-Khalick & Lederman, 2000b; Akerson et al., 2000; Doğan, Çakıroğlu, Çavuş, Bilican, Arslan, 2011; Lin & Chen, 2002; McDonald, 2010; Morgil, Temel, Güngör, & Ural Alşan, 2009). Although these efforts was found to be effective in enhancing teachers' NOS understanding, research on the transformation of teachers' conceptions into classroom practice indicated that teachers' conceptions of NOS can be thought of as a necessary but not sufficient condition for effective NOS instruction. There are numerous factors explaining what impede teachers' direct translation of their NOS understandings into their classroom teaching: beliefs and intentions (Abd-El-Khalick et al., 1998; Bell, Lederman, & Abd-El-Khalick, 2000; Lederman, 1999; Lederman, Schwartz, Abd-El-Khalick, & Bell, 2001; Schwartz & Lederman, 2002), pedagogical skills and teaching experience (Abd-El-Khalick et al., 1998; Brickhouse & Bodner, 1992; Lederman, 1999; Lederman et al., 2001); classroom management and organization (Abd-El-Khalick et al., 1998; Bell et al., 2000; Hodson, 1993; Lederman, 1995; Lederman, 1999); knowledge of subject matter (Lederman et al., 2001); pressure to cover content (Abd-El-Khalick et al., 1998; Hodson, 1993); concern about not being able to spend enough time for teaching basic knowledge of science because of the time allocated for NOS teaching (Lederman, 1999); concerns about students' abilities and motivation for learning NOS (Abd-El-Khalick et al., 1998; Brickhouse & Bodner, 1992; Lederman, 1999); institutional constraints (Brickhouse & Bodner, 1992); constraints imposed by cooperating teachers, in the case of pre-service teachers (Abd-El-Khalick et al., 1998; Bell et al., 2000), and context where teaching occurs (Akerson, Cullen, & Hanson, 2009). In addition to these factors, studies provided evidence for other factors which are specific to teaching NOS directly such as NOS teaching self-efficacy, NOS content knowledge, lack of resources and experience for teaching and/or assessing understandings of the NOS, and subject-specific pedagogical knowledge for teaching NOS (Abd-El-Khalick et al., 1998; Akerson et al., 2009; Bell et al., 2000; Lederman, 1999; Lederman et al., 2001).

Subject-specific knowledge for teaching is called as pedagogical content knowledge (PCK) and when it is applied to NOS, subject specific knowledge for teaching NOS becomes PCK for NOS. PCK for NOS has been stressed as crucial for ensuring teachers' translation of their contemporary NOS understandings into successful NOS classroom instruction (Abd-El-Khalick & Lederman, 2000a; Hanuscin, Lee, Akerson, 2011; Lederman et al., 2001; Schwartz & Lederman, 2002). How could science educators help teachers in developing their PCK for NOS? An important solution for this problem is that providing teachers with the opportunities for studying the subject matter such as NOS from a teaching perspective (van Driel, Verloop, & de Vos, 1998). Studying NOS from a teaching perspective leaves science educators with a difficult task of involving teachers in activities stimulating their PCK for NOS.

PCK is a specialized professional knowledge unique to teachers and it discriminates a science teacher from a scientist (NRC, 1996). Shulman is the first to conceptualize PCK. He delineated it as the knowledge "which goes beyond knowledge of subject matter per se to the dimension of subject-matter knowledge for teaching" and he continues "the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations-in a word, the ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1986, p. 9). PCK is topic-specific and science teachers have different PCK for different topics in science. Considering NOS as a topic in science (Lederman, 1998) entails a specific conceptualization for PCK for NOS. When PCK is applied NOS teaching, PCK for NOS include

> … an adequate understanding of various aspects of NOS, knowledge of a wide range of related examples, activities, illustrations, explanations, demonstrations, and historical episodes. These components would enable the teacher 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 adapt those aspects to the diverse interests and abilities of learners (Abd-El-Khalick & Lederman, 2000a, p. 692).

In other words, PCK for NOS is the knowledge of a science teacher that makes NOS aspects understandable and accessible to different groups of students. PCK for NOS was also defined by Schwartz and Lederman (2002) as a blending of subject-matter knowledge, NOS knowledge, and pedagogical knowledge. In another study, Kim, Ko, Lederman, and Lederman (2005) extended that model in terms of subject matter knowledge, relevant knowledge of the scientific concept, such as the history of its development and its empirical grounds. In addition, they asserted that NOS-specific pedagogical knowledge includes knowledge of the difference between an implicit and an explicit approach and between a didactic and an explicit and reflective approach.

Hanuscin et al. (2011) and Hanuscin and Hian (2009) adapted Magnusson, Krajcik, and Borko's (1999) PCK for science teaching model and used that model as a lens for research on nature and development of teachers' PCK for NOS. They focused on science teachers' science teaching orientation (STO), knowledge of learners (KoL), knowledge of instructional strategies (KoIS), knowledge of curriculum (KoC), and knowledge of assessment (KoA) from the perspective of NOS. Both studies indicated the applicability of Magnusson et al.'s (1999) model as a lens for research on PCK for NOS and uneven development of teachers' PCK for NOS. That is, change in KoIS was not accompanied by the changes in KoA. These studies suggested that professional development efforts could be enhanced by focusing on improving all aspects of teachers' PCK for NOS, rather than focusing solely on particular aspects. Different than abovementioned studies, several studies focused on the effect of interventions on teachers' ability to teach NOS (Akerson & Abd-El-Khalick, 2003; Akerson &Volrich, 2006). They examined whether teachers successfully translated their NOS understanding into classroom practice without using any PCK for NOS framework. Results of these studies indicated that interventions were effective in helping teachers to teach several NOS aspects in their classes in some extend. However, both studies clearly suggested a professional development support specific for NOS and PCK for NOS.

Consequently, there is an increasing emphasis for the necessity of professional development that should enable teachers to develop and revise existing materials rather than simply to use the results of others' work (Schwartz &

Lederman, 2002) and enhance teachers' PCK for NOS with regard to all dimensions (e.g., instructional strategies, learner, assessment, curriculum) for effective NOS instruction (Akerson & Abd-El-Khalick, 2003; Akerson &Volrich, 2006; Hanuscin & Hian, 2009; Hanuscin et al., 2011). Moreover, there are few studies using a particular framework for examining the nature and development of PCK for NOS (e.g., Hanuscin et al., 2011; Hanuscin & Hian, 2009) and it is clear that teachers' PCK for NOS is an area of research that needs to be investigated (Lederman et al., 2001).

1.1. Purpose of the Study

The purpose of this study was to trace the development of pre-service chemistry teachers' pedagogical content knowledge for nature of science with regard to their science teaching orientation, knowledge of learner, knowledge of instructional strategy, and knowledge of assessment during pedagogical content knowledge for nature of science instruction.

1.2. Research Questions

The main research question of the study is:

How does pre-service chemistry teachers' PCK for NOS including STO, KoL, KoIS, and KoA develop throughout PCK for NOS instruction?

The sub-problems of this study are:

1. What kinds of views do the preservice chemistry teachers have on the nature of science concepts before explicit-reflective NOS instruction?
2. What kinds of views do the preservice chemistry teachers have on the nature of science concepts after explicit-reflective NOS instruction?
3. Which components of PCK for NOS do pre-service chemistry teachers develop throughout PCK for NOS instruction?
4. How and to what degree do pre-service chemistry teachers integrate the components of their PCK for NOS?

5. How and to what degree dopre-service chemistry teachers translate PCK components into their lesson plans?
6. How are pre-service chemistry teachers' NOS understanding and their PCK for NOS related?
7. Which PCK model (general PCK, discipline-specific PCK, or topic specific PCK) best explains the nature of PCK for NOS?

1.3. Definitions of Important Terms

NOS: NOS refers to the epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its' development (Lederman, 1992). NOS not only conveys an understanding on scientific processes including the studies of scientists but also products of science (Meichtry, 1993).

Understanding of NOS: An understanding of NOS includes the answers given to the questions of "What is science?", "How it works?", "How scientists as a social group work?", and "How society directs science and reacts to scientific endeavor?" (McComas & Olson, 1998). Students' NOS understandings convey their conceptions on agreed upon NOS aspects accessible to pre-college students (AAAS, 1993; McComas & Olson, 1998; NRC, 1996); scientific knowledge is tentative; empirical; theory-laden; partly the product of human inference, imagination, and creativity; and socially and culturally embedded. Three additional important aspects are the distinction between observation and inference, the lack of a universal method for doing science, and the functions of and relationships between scientific theories and laws.

PCK for NOS: PCK for NOS include

> … an adequate understanding of various aspects of NOS, knowledge of a wide range of related examples, activities, illustrations, explanations, demonstrations, and historical episodes. These components would enable the teacher 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 adapt those aspects to the diverse interests and abilities of learners (Abd-El-Khalick & Lederman, 2000a, p. 692).

PCK for NOS instruction: Magnusson et al.'s (1999) PCK model formed the basis of PCK for NOS instruction. PCK for NOS instruction mainly consisted of two parts. In the first part, pre-service teachers learned about NOS (spanned one and half semester) in an explicit reflective manner. Following the learning NOS part, in the second part (spanned four weeks corresponds to 16 course hours), pre-service chemistry teachers engaged in activities designed to enhance four main dimensions of their PCK considering Magnusson et al.' model which are STO, KoL, KoIS, and KoA.

STO: Science teaching orientation is defined as "teachers' knowledge and beliefs about the purposes and goals for teaching science at a particular grade level" (Magnusson et al., 1999, p. 97).

KoL: KOL is the knowledge and beliefs about students' understanding of specific science topics (requirements for learning specific science concepts, and areas of science that students find difficult including misconceptions) (Magnusson et al., 1999).

KoIS: KoIS is the teachers' knowledge of strategies and representations for teaching particular topics (Magnusson et al., 1999). This knowledge comprises of two categories: knowledge of subject-specific strategies, and knowledge of topic specific strategies. The subject-specific strategies are broadly applicable; they are specific to teaching science as opposed to other subjects. The topic-specific strategies are much narrower in scope; they apply to teaching particular topics within a domain of science.

KoA: KoA comprises two categories as knowledge of the dimensions of science learning that are important to assess, and knowledge of the methods by which learning can be assessed (Magnusson et al., 1999).

Explicit-reflective NOS instruction: This approach intentionally draws learners' attention to aspects of NOS through discussion, guided reflection, and specific questioning in the context of activities, investigations, and historical examples.

1.4. Significance of the Study

This study fulfills several gaps in literature on examining and facilitating teachers' translation of their NOS understandings into effective NOS teaching and addresses several issues in science teacher education.

Studies showed that even when science teachers have informed understandings of NOS, they generally do not explicitly teach NOS, or may do so through didactic approaches which are ineffective (Schwartz & Lederman, 2002). This finding indicates the necessity of efforts not only to increase teachers' NOS understandings but also to help them in how to effectively teach NOS to their students. Moreover, studies examining factors affecting teachers' translation of their NOS understandings into effective classroom instruction revealed the importance of teachers' beliefs in significance of NOS learning and intentions for teaching NOS (Abd-El-Khalick et al., 1998; Bell et al., 2000; Lederman, 1999; Lederman et al., 2001; Schwartz & Lederman, 2002) and there is a lack of research on providing guidance for how to develop teachers' valuing of NOS (Lederman, 2007). In this study, the PCK for NOS instruction intends to accomplish the task of helping science teachers in considering NOS as one of the important science learning outcomes since it guides teachers to reflect and revise their STO in a way to consider NOS. Also, the instruction supports teachers in designing effective NOS teaching.

Although PCK for NOS has been advocated as one of the crucial factors that facilitate teachers' successful translation of their NOS understanding into classroom teaching (Abd-El-Khalick et al., 1998; Akerson et al., 2009; Bell et al., 2000; Lederman, 1999; Lederman et al., 2001), teacher educators have been less successful in helping teachers enhance their PCK for NOS (Hanuscin & Hian, 2009). For enhancing teachers' PCK for NOS, providing teachers with a series of activities will not be adequate (Ochanji, 2003). There is a obvious call for professional development that should enable teachers to develop their own materials (Schwartz & Lederman, 2002) and enhance teachers' PCK for NOS with regard to all dimensions to be considered for affective NOS instruction (e.g., instructional strategies, learner, assessment, curriculum) (Akerson & Abd-El-Khalick, 2003; Akerson &Volrich, 2006; Hanuscin & Hian, 2009; Hanuscin et al., 2011). This study including a PCK for NOS instruction may lead to science teacher educators for designing effective professional development programs for science teachers.

In terms of the issues of research on NOS teaching, it has been emphasized that the development and especially nature of teachers' PCK for NOS is an area of research that should be examined deeply (Lederman et al., 2001). "Virtually no research has used the PCK perspective, which was so heavily researched during the 1990s, as a lens for research on the teaching of NOS" (Lederman, 2007, p. 870). The number of studies using the PCK framework for the research on teaching NOS is relatively low (Faikhamta, 2012; Hanuscin et al., 2011; Hanuscin & Hian, 2009). This study will contribute to research on NOS teaching by utilzing a particular PCK framework (Magnusson et al., 1999). The PCK for NOS (Magnusson et. al., 1999) framework utilized in this study may provide a deeper understanding of why teachers may fail to enact particular practices. Another point that needs consideration is that there is a need to examine the interplay between various components of teachers' PCK for NOS (Hanuscin et al., 2011) and investigation of how PCK components interact with each other is highly recommended (Abell, 2008). This study regarded the interaction among the PCK components and hence was able to evaluate the quality of pre-service chemistry teachers' PCK for NOS since the quality depends on degree of integration and coherence among its' components (Friedrichsen et al, 2009; Magnusson et al., 1999; Park & Oliver, 2008a). The results of this study will contribute to not only research on PCK but also on PCK for NOS. Also, comparing and contrasting nature of PCK and PCK for NOS will shed light on nature of PCK for NOS. There have been several models for PCK as general PCK (Veal & MaKinster, 1999), topic specific (Lederman, 1998), and discipline specific (Davis & Krajcik, 2005). Which one of these models can fully capture the essence of teachers' translation of their NOS understanding into classroom? This study will delve into the complexities on nature of PCK for NOS and add to research on both PCK and PCK for NOS.

CHAPTER II

LITERATURE REVIEW

The purpose of this study was to delve into the complexities of pre-service chemistry teachers' STO, KoL, KoIS, and KoA development during PCK for NOS instruction. Therefore, literature on what NOS is, teachers' understanding of NOS, factors affecting teachers' translation of their NOS understanding into class, PCK, and finally PCK for NOS will be reviewed in this chapter.

2.1. Nature of Science

Having an adequate understanding about NOS has been identified as vital in science education reform and an essential part that contributes to students' SL (AAAS, 1993; Bauer, 1995; Layton et al., 1994; NRC, 1996; Shamos, 1995). Therefore, what is meant by NOS and to what extend students should learn NOS has been an issue to be resolved among philosophers of science and science educators. Although they were not able to reach a clear-cut definition of NOS accepted by all interested in NOS (Abd-El-Khalick & Lederman, 2000a), there are some agreed ideas on the NOS aspects that should be communicated to K-12 students for achieving SL. Thus, first of all, I will present and discuss various ideas on NOS and then explain what constitutes NOS in this study.

Typically, NOS refers to the epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its' development (Lederman, 1992). NOS not only includes an understanding on nature of scientific knowledge but also scientific enterprise (Meichtry, 1993). One of the earlier studies for clarifying what is meant by NOS was conducted by Kimball (1968). Kimball, in his extensive study of the literature on the nature and philosophy of science, proposed a theoretical model of the NOS focusing on eight aspects of science:

> (1) curiosity is the fundamental driving force in science and science concerns with production of new knowledge; (2) science is a dynamic rather than a static accumulation of information; (3) science aims at comprehensiveness and simplification emphasizing mathematical language as the most precise and simplest means of stating relationships; (4) there are many methods of science as there are practitioners; (5) the methods of science are characterized by attitudes which are more in the realm of values than techniques such as dependence upon sense experience, insistence on operational definitions, recognition of the arbitrariness of definitions, schemes of classification, and evaluation of scientific work in terms of reproducibility; (6) a basic characteristic of science is a faith in the susceptibility of the physical universe to human ordering and understanding; (7) science has a unique attribute of openness in mind and in the realm of investigation; and (8) tentativeness and uncertainty mark all of science. Nothing is ever completely proven in science (p. 275).

After the work of Kimball (1968), Rubba and Anderson (1978) defined a model called A Model of the Nature of Scientific Knowledge. This model included six factors explaining the nature and characteristics of scientific knowledge. According to this model scientific knowledge is amoral (it cannot be judged as morally good or bad), creative (it is partially a product of human creativity), developmental (it is tentative), parsimonious (it attempts to achieve simplicity of explanation instead of complexity), testable (it is capable of empirical test), and lastly unified (the specialized sciences contribute to an interrelated network of laws, theories, and concepts). Approximately 10 years after Rubba and Anderson (1978), AAAS (1989) defined NOS focusing on SL as an essential for individuals living in a scientifically literate society and introduced three main themes for NOS as;

1. The scientific world view: The world is understandable, scientific ideas are subject to change, scientific knowledge is durable, and science cannot provide complete answers to all questions.

2. Scientific inquiry: Science demands evidence, science is a blend of logic and imagination, science explains and predicts, scientists try to identify and avoid bias, and science is not authoritarian.
3. The scientific enterprise: Science is a complex social activity, science is organized into content disciplines and is conducted in various institutions, there are generally accepted ethical principles in the conduct of science, and scientists participate in public affairs both as specialists and as citizens.

Studies beginning with Kimball and the subsequent ones drove a debate on teaching and learning about the NOS among researchers, resulting in a growth in the related literature. For example, Alters (1997) examined NOS views of 210 science philosophers with a doctoral degree who were the members of the Philosophy of Science Association (PSA) by using an instrument including 20 items. The first 15 items of this instrument were directed towards identifying the degree to which science philosophers agreed with the NOS tenets. These tenets were: 1. The fundamental driving force in science is curiosity concerning the physical universe, 2. Science aims at ever-increasing comprehensiveness and simplifications using mathematics as a simple, precise method of stating relationships, 3. The methods of science are better characterized by some value-type attributes than by techniques. Item 16 asked the participants to add or delete one of the NOS tenets. Remaining three items were related to how science philosophers viewed and defined science. Results revealed that science philosophers varied on their views about the tenets. Alters (1997) concluded that "…there is no one agreed-on philosophical position underpinning the existing NOS in science education" (p. 48) and therefore, science educators should employ a pluralistic approach by which students have the opportunity to interpret science from different philosophical positions (e.g., empiricism or radical constructivism).

As a response to Alters' (1997) study, Smith, Lederman, Bell, McComas, and Clough (1997) expressed their concerns related to this study and strongly disagreed with its conclusion for several reasons. Firstly, Smith et al. (1997) stated that there were problems with the selection and wording of items and more importantly with the interpretations of the survey data. They admitted that there was substantial divergence among science philosophers’ views regarding the contribution of philosophies to science (e.g., priorism and conventionalism); however, to them, much of this disagreement was not relevant to K–12 education. Smith and colleagues recommended that K–12 teachers should ignore Alters’ study and concluded that “…too much is being made of disagreements concerning the NOS tenets are esoteric, inaccessible, and probably inappropriate for most K–12 instruction” (p. 1102).

Another opponent view to Alters’ study, especially to its pluralistic approach, was proposed by Smith and Scharmann (1999). They advocated that instead of learning the various philosophical viewpoints about science, students need a sound understanding of NOS which help them in making informed decisions in order to be rationale consumers of scientific knowledge. Smith and Scharmann (1999) proposed that students should learn and judge the characteristics that qualify something more or less scientific. They identified the following characteristics;

- Science is empirical.
- Scientific claims are testable / falsifiable.
- Scientific tests or observations are repeatable.
- Science is tentative / fallible.
- Science is self-correcting.
- Science places a high value on theories that have the largest explanatory power.
- Science values predictive power.
- Science values fecundity
- Science values open-mindedness.
- Science values parsimony.
- Scientists demand logical coherence in their explanations.
- Scientists value skepticism.

What should be taught to K-12 students has been an issue of concerns among science educators. As a solution to this issue, McComas and Olson (1998) qualitatively analyzed science education standards documents. The analysis revealed that there was an evidence for the contribution of four disciplines to our understanding of science, namely philosophy, history, sociology, and psychology of science. Table 1 displays how each discipline contributes to science by responding appropriate questions about science.

Table 1. Contribution of various disciplines to our knowledge on science

Philosophy of science	What is science? How is it done? What is the nature of scientific knowledge?
History of science	How is science perceived by the society and operated during the history?
Psychology of science	What are the characteristics of scientists?
Sociology of science	Who are scientists? How do scientists work?

In addition to the contribution of different fields to science, analysis of standards documents indicated that that there was a consensus about the following elements of the NOS that should be communicated to students (McComas & Olson, 1998);

- Scientific knowledge while durable, has a tentative character.
- Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, and skepticism.
- There is no one way to do science (therefore, there is no universal step-by-step scientific method).
- Science is an attempt to explain natural phenomena.
- Laws and theories serve different roles in science; therefore students should note that theories do not become laws even with additional evidence.
- People from all cultures contribute to science.
- New knowledge must be reported clearly and openly.
- Scientists require accurate record keeping, peer review and replicability.
- Observations are theory-laden.
- Scientists are creative.
- The history of science reveals both an evolutionary and revolutionary character.
- Science is part of social and cultural traditions.
- Science and technology impact each other.

- Scientific ideas are affected by their social and historical milieu.

After the work of McComas and Olson (1998), Osborne and his colleagues (2003) conducted a study using Delphi technique in order to determine what should be communicated to students about NOS with the participation of 23 individuals including international experts of science educators; scientists; historians, philosophers, and sociologists of science; experts engaged in work to improve the public understanding of science; and science teachers. Osborne et al. (2003) in the first round of their three-round study searched for the participants' opinions on the following questions: (a) What, if anything, do you think should be taught about the methods of science? (b) What, if anything, do you think should be taught about the nature of scientific knowledge? and (c) What, if anything, do you think should be taught about the institutions and social practices of science? In the second round, participants rated and justified the importance of each 30 themes, emerged in the first round, in terms of school science curriculum. In the third and final round, they deduced the number of themes and came up with the following nine themes, reaching a considerable level of agreement:

- Science and Certainty
- Analysis and Interpretation of Data
- Scientific Method and Critical Testing
- Hypothesis and Prediction
- Creativity
- Science and Questioning
- Cooperation and collaboration in the development of scientific knowledge
- Science and Technology
- Historical Development of Scientific Knowledge
- Diversity of Scientific Thinking

In a recent study, Irzık and Nola (2011) proposed a family resemblance approach in order to portray a deep understanding of NOS for the science educators. "The basic idea of a family resemblance definition turns on the fact that the members of a family can each resemble one another in some respects but not in others" (p. 594). When applied to science, Irzık and Nola (2011) stated that there were characteristics common to all sciences but they cannot be used for demarcation.

Rather, they advocated that family resemblance approach describes the ways in which the sciences are similar or dissimilar. The following categories give a description of NOS using family resemblance approach and provide the aspects that should be considered when comparing different disciplines in science: (1) activities, (2) aims and values, (3) methodologies and methodological rules, and (4) products. Irzık and Nola (2011) advocated that this approach was more powerful than the others presenting list of the NOS tenets since it depicts the open-ended and dynamic NOS. Moreover, the family resemblance approach is pedagogically effective as it provides teachers the opportunity of focusing on any categories and discuss an aspect of science relevant to the class.

Different than the aforementioned studies aiming to define NOS, McComas (1998) discussed NOS myths, which refers to misconceptions, and proposed that these myths should be considered while teaching NOS. Since these misconceptions are common, they provide a more comprehensive NOS understanding for classroom instruction when considered with NOS aspects to be communicated. The common 15 myths identified by McComas (1998) are as follows;

- Hypotheses become theories that in turn become laws.
- Scientific laws and other such ideas are absolute.
- A hypothesis is an educated guess.
- General and universal scientific method exists.
- Evidence accumulated carefully will result in sure knowledge.
- Science and its methods provide absolute proof.
- Science is procedural more than creative.
- Science and its methods can answer all questions.
- Scientists are particularly objective.
- Experiments are the principal route to scientific knowledge.
- Scientific conclusions are reviewed for accuracy.
- Acceptance of new scientific knowledge is straightforward.
- Science models represent reality.
- Science and technology are identical.
- Science is a solitary pursuit.

As science educators, we cannot expect teachers or students to become historians, psychologists, sociologists, or philosophers of science. Therefore, the aim of introducing NOS in classroom should have been clarified: "a more complex understanding of science, not a total or even a very complex understanding" (Matthews, 1998, p. 168). This more complex understanding of science includes an understanding of what science is, how it works, the epistemological and ontological foundations of science, how scientists operate as a social group and how society itself both influences and reacts to scientific endeavors. Although there have been some disagreements on a specific definition on NOS, there are some agreed upon important aspects of NOS which is relevant and accessible to K-12 (Abd-El-Khalick et al., 1998; Lederman & Abd-El-Khalick, 1998; McComas & Olson, 1998; Osborne et al., 2003; Smith &Scharmann, 1999). The following aspects constituted our understanding of NOS and reflect the contemporary understanding on NOS as defined by literature.

Scientific knowledge is tentative: Although scientific knowledge is durable, it changes with the new data or reinterpretations of existing ones. This change might be a complete (e.g., phlogiston theory vs. oxygen theory) or partial change (e.g., atom theories). It is impossible to test every possible situation for a scientific knowledge. Therefore, scientists are not able to prove a scientific knowledge, instead they just merely support the existing knowledge and no one can guarantee, in the future, there might be a new data by which current scientific knowledge might be inadequate to explain.

Science is based on observations and experiment: Science and scientific knowledge are based on observations and experiments. Scientists use observations and experiments when appropriate to test the validity of their claims. Not every scientific discipline enables scientists to conduct experiments such as astronomy or not all scientific knowledge is constructed as a result experiments such as evolution theory. Therefore, experiments and observations play vital role in science to reach scientific knowledge when used properly.

Scientific knowledge is based on inferences as well as observations: Scientific knowledge is the inferences derived from observations. Observations are descriptive statements about phenomena obtained by using senses (e.g., sight, hearing, touch, smell and taste) or some technological devices (e.g., using scale to measure mass). However, inferences are the interpretations of these observations (e.g., Rutherford's atom model based on his observations on the number of alpha particles passed, scattered through and reflected from gold foil).

Scientific theories and laws have different roles in science: Scientific theories and laws have different meanings and roles in science. Scientific laws are the descriptive statements about the perceived relationships, regularities, patterns, and generalizations in nature. On the other hand, scientific theories are the explanations for phenomena or laws. For instance, while Boyle's law describes the relationship between pressure and volume of a gas, kinetic molecular theory explains why there is such a relationship between pressure and volume. There is no hierarchical relationship between theory and law since it is impossible for a theory to become a law considering their role in science. Also, scientific theories and laws are tentative as they are scientific knowledge and there is no status difference between them in terms of reliability and changeability.

Scientific knowledge is theory-laden and includes subjectivity: Throughout a scientific study, in all phases, for scientists it is impossible to achieve complete objectivity. When scientists develop questions, design investigations, and make observations and inferences, their previous knowledge, experiences, expectations, and theories and laws that they believe unavoidably affect them. For instance, Millikan excluded some his oil drop experiment results because of his belief in atomic theory while Ehrenhaft included all the results based on his belief in anti-atomic theory. Considering all the factors influencing scientists throughout their work, scientific knowledge is theory-laden and includes subjectivity.

Creativity and imagination plays a major role in science: Logic by itself is not sufficient enough for science and creativity and imagination are required during various phases of a scientific study such as constructing hypothesis, designing different ways for observations and experiments, finally interpretation of data.

Social and cultural factors affect science: Science cannot be isolated from the social and cultural environment in which it is conducted. Politics, religion, philosophy, economy, moral values are some of the factors which influence deciding what and how science is conducted, interpreted and developed. In addition, scientific knowledge is produced, presented, and evaluated in social contexts including groups of scientists and scientific organizations.

Science and technology is not the same thing: Science and technology are confused with each other since in today's world most of the technological developments are presented as scientific development in popular media. Science and technology are different from each other with regard to their purposes, methods, and products. Purpose of science is to explain natural world while technology seeks solutions for human's problems they encountered during adaptation to natural world and hence tries to make the life easier. In addition, scientists use scientific inquiry methods such as hypothesis testing and experimenting while technicians use problem solving strategies such as technological design and construct. From the perspective of products, scientific knowledge is product of science and designs which are solutions for peoples' needs are products of technology. More importantly, technology is not the application for science since some technological devices are discovered before the underlying scientific knowledge is produced.

There is no universal and step by step scientific method: Most people believe that there is a universal and step by step scientific method which is used by all the scientists around the world. These commonly believed steps that constitute the method are a) defining the problem, b) gathering background information, c) forming a hypothesis, d) making observations, e) testing the hypothesis, and f) drawing conclusions. History of science provides examples for eliminating the myth in the belief for following the aforementioned steps. For instance, Darwin proposed the theory of evolution right after his observations in Galapagos Islands without forming a priori hypothesis. There are several common scientific processes such as forming hypothesis, observation, experimentation, interpretation, and hypothesis testing but these processes do not have to follow a specified order.

Serendipity plays a role in science: Serendipity is a term used for describing the interaction of logic and chance during a scientific discovery. There are various examples of scientific discoveries where chance plays an important role such as penicillin and X-rays. During these discoveries, scientists were looking for something but an unexpected and unplanned another thing was occurred. Just chance is not enough for a scientist to discover new phenomena. Scientists paid attention to these things and interpreted it using their logic, and as a result, produced a scientific knowledge different than the one which they intended to investigate.

After critically looking at the NOS literature and defining our understanding of NOS that would be communicated to pre-service chemistry teachers, the next step was to portray a clear picture of what teachers know about aforementioned NOS aspects. Teachers' NOS understanding refers to their subject matter knowledge (SMK) in this study and is a pre-requisite for a well-developed PCK for NOS (van Driel et al., 1998). Therefore, identifying teachers' understanding of NOS is crucial for designing a more effective PCK for NOS instruction since first part of PCK for NOS instruction aims to increase teachers' NOS understanding.

2.2. Teachers' Understanding of NOS

Earlier attempts related to investigation of teachers' NOS concepts dates back to 1950s, but careful consideration of teachers' NOS understanding started at the beginning of 1990s since NOS emerged as a prerequisite for achieving SL in science education reform movements. Lederman (1992) reviewed the studies between 1950 and 1992 and concluded that teachers do not have informed understanding of NOS irrespective from the instruments used to assess their understandings. After the beginning of 1990s, science educators used various instruments and categorizations for identifying and describing the way teachers' thinking about NOS.

Abd-El-Khalick and BouJaoude (1997) defined 20 in-service science teachers' knowledge base about the structure, function, and development of their discipline, and their NOS understandings. For assessing NOS, they used 22-item version of Views on Science-Technology-Society (VOSTS) and concept mapping associated with interviews. The items were about the nature of observations, scientific models, and classification schemes, the tentativeness of scientific knowledge, precision and uncertainty in scientific knowledge, logical reasoning in science, and the epistemological status of scientific knowledge. Results of this study revealed that there was little evidence for teachers' informed understanding of NOS. Considering different dimensions assessed by VOSTS, distribution of informed views varied between 38% and 67% and while the naive views ranged between 33%

and 62%. The percentages of teachers having naive NOS conceptions in different dimensions were as below;

- There is a universal and step by step scientific method followed by all scientists (94%).
- The difference between competent and incompetent scientists is to follow the scientific method (88%).
- Scientific models are copies of reality rather than human inventions (47%).
- Science is universal and there is no place for the theories in guiding scientific research (82%).
- Observations are not theory-laden (71%).
- There is a hierarchical relationship between hypothesis, theory and law (59%).
- Scientists do not make assumptions in their work (59%)

Haidar (1999) explored 31 pre-service science and 224 in-service chemistry teachers' views on NOS using a five-dimensional NOS questionnaire prepared by using various items from different NOS scales. The questionnaire was consisting of items reflecting the beliefs of traditional and constructivist views about science. Traditional view suggests that: "…science is merely a means of revealing the natural laws of God that regulate a clockwork universe; the only way to gain scientific knowledge is through the application of the induction method; scientists are objective free from illusion and myths of the past; and scientific knowledge is absolute and devoid of creativity and human imagination" (p. 807). On the contrary constructivist views refers to contemporary views of NOS (e.g., theory-ladennes of observation, there is no step by step and universal scientific method). Scientific theories and models, role of scientists, scientific knowledge, scientific method and scientific laws were the focus of the study in relation to NOS. Overall, both pre-service and in-service teachers demonstrated neither traditional nor constructivist about NOS. The percentages of teachers holding traditional views about science were as below (Table 2);

Table 2. The percentages of teachers holding traditional views about science in Haidar (1999)'s study

	Pre-service	In-service
Scientific theories		
Theory-ladennes of observations	55	47
Discovery of scientific theories	81	81
Hierarchical relationship between hypothesis, theory, and law	97	76
Rejection of scientific theories and models	26	14
Scientific models		
Role of a scientist	29	32
The scientific method	48	52
Recording data	55	59
Evaluation of scientific ideas	52	44
Subjectivity	58	49
Purpose of science	26	33
Scientific knowledge		
Cumulative nature	48	68
Tentativeness*	10	25
Sources*	10	25
Generation*	10	25
Scientific method		
Step by step method	65	75
Single method	19	36
Scientific laws		
Invention of laws	71	71
Nature of laws	39	39

* values indicates the ranges not the exact values

Murcia and Schibeci (1999) investigated the major conceptions of the NOS held by a sample of pre-service primary school teachers. They used a newspaper science report to help participants articulate their views of the NOS. Sample consisted of 73 volunteer students who were enrolled in an introductory physical science unit for primary pre-service teachers. Result of the study showed that over 70% of the respondents answered in a way consistent with the new philosophy on eight of 15 true/false statements, which suggests the following views on the NOS: Scientists have shared beliefs and attitudes about their work and, in turn, the spreading of scientific information is important to progress in science. A strong conception of scientists' work being affected by personal beliefs, values and background existed in the study group. Responses to other statements showed a relatively high degree of uncertainty and inconsistent views with the new philosophy of science. Generally, the respondents displayed a naive and unclear understanding of scientific method-the discovery of “truth” through observations. The respondents also showed a poorly developed understanding of scientific theory. There was little awareness of the social context of science and scientists’ work in the responses.

In another study with pre-service teachers, Chen (2001) explored prospective science teachers’ (biology, chemistry, earth science, and physics) NOS conceptions and the relationship between their conceptions and majors, if any. 14 prospective secondary science teachers at three different universities completed the questionnaire on NOS and follow-up interviews. It was found that prospective science teachers from different disciplines varied in their views on NOS and attitudes toward teaching NOS. Prospective teachers in all science majors hold strong beliefs in the value of scientific knowledge; the tentative nature of science; realism (scientific studies seek truths about the world); hierarchical relationship of hypotheses, theories, and laws; and the existence of universal scientific method.

In a similar study, pre-service and in-service science teachers’ views about 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 was explored (Tairab, 2001). The data for the study were collected using eight items selected from Nature of Science and Technology Questionnaire (NSTQ) and with the participation of 41 pre-service and 54 in-service science teachers. Although the majority of science teachers held realistic views about science, its aim and the nature of scientific research and the nature of technology was naively conceived by the science teachers. The majority of both groups of science teachers held the view that supports the tentativeness of scientific knowledge. On the other hand, 22% and 24% of the pre-service and in-service science teachers, respectively, held static views about scientific knowledge. They also supported the view that science is a collection of facts or a body of knowledge that explains the world and that the purpose of scientific research is to collect as much data as possible. Over half of both groups of science teachers conceived a scientific theory as “the most appropriate explanation and interpretation put forward by scientists" (p. 242). In addition, similar percentages of both groups of science teachers (29.3% of pre-service and 29.6% of in-service science teachers) confused a scientific theory with a scientific fact suggesting that theories were facts before being proven by experiments.

Two years later, Thye and Kwen (2003) examined preservice chemistry teachers' conceptions of NOS. Views of Nature of Science (VNOS) Questionnaire was administered to 125 preservice teachers. The modified instrument is an eight-item, open ended questionnaire designed to elicit descriptive responses to common NOS misconceptions. Responses were analyzed into coded categories of informed, ill-informed, and ambiguous. 76% of students believed the necessity of experimentation to forward the development of science. 46% of the participants showed ill-informed views and 37% showed ambiguous views on scientific theory is a hypothesis that has not been proven yet. The view that "models are the copies of reality" was ill-informed by 42% of the students. 24% of the participants believed that the science is universal and 74% of the students had ill-informed or ambiguous views on the definition of science. Interestingly, most of the teachers had informed views on the tentative nature of scientific knowledge.

Erdoğan (2004) investigated the views of pre-service science teachers on NOS. A total of 166 preservice science teachers from three different universities participated in the study. 21 items selected from the epistemology of science category of the VOSTS instrument. In order to understand participants' views on NOS in depth, semi-structured interviews were also conducted by nine volunteer pre-service science teachers. Results of this study revealed that pre-service science teachers held naive views on the definition of science; the nature of scientific models; the relationships between hypotheses, theories, and laws; fundamental assumptions for all science; the scientific method; uncertainty in scientific knowledge; epistemological status of scientific knowledge; coherence of concepts across disciplines. On the other hand, participants had realistic views on the nature of observation; the nature of classification schemes; the tentativeness of scientific knowledge; cause and effect relationship.

In a comprehensive study, Doğan (2005) investigated the views of physics, chemistry, biology teachers and 10^{th} class math-science students on NOS in Turkey.

A total of 1994 students and 362 teachers (125 physics, 124 chemistry and 123 biology teachers) chosen from science high schools and Anatolian high schools in 21 cities of seven geographical regions participated in the study. In order to assess the views of participants on NOS, a total of 25 questions from VOSTS (science, the characteristics of science person, the social structure of scientific knowledge, the effects of science and technology on society, the effects of society on science and technology, the characteristics scientific knowledge) were translated and adapted into Turkish. Each statement in a VOSTS item was categorized into one of the three categories: realistic (an appropriate view), has-merit (expresses a number of legitimate points) and naive (an inappropriate view). Results of this study revealed the misconceptions of teachers and students on NOS. In addition, the participants held traditional views on the definition of the nature of scientific models, the relationships between hypotheses, theories, and laws, the scientific method, fundamental assumptions of science, epistemological status of scientific knowledge and relationships between disciplines while they have contemporary (realistic) views on the scientific observations, the nature of classification schemes, the tentativeness of scientific knowledge, and cause and effect relationships. Naive views of the teachers and the corresponding percentages were:

- Scientists are objective (81%).
- Scientific models are the copies of reality (63.3%).
- Science is universal and is not affected by social and cultural values (28.2%).
- Scientific laws are absolute and do not change (13%).
- Gender makes a difference in scientific studies and discoveries (44.7%).
- Scientific method is necessary to acquire a scientific knowledge (31%).
- There is a hierarchical relationship among hypothesis, theory and law. Hypothesis becomes theory if it is proven to be true and theory becomes law if it is universalized (85.6%).
- Theories are discovered rather than invented (33.8%) .
- Laws are discovered rather than invented (34%).
- Experiment is necessary for development of scientific knowledge (88.8%).

In a study, chemistry student teachers' and classroom student teachers' ideas on the science and the NOS was evaluated (Gürses, Dogar, & Yalçın, 2005). The essay type questions concerning the scientific theory, the nature of theory and the nature of law were asked and responses were taken in written format from 37 pre-service chemistry and 78 elementary teachers. It was found that the student could not differentiate theoretically and empirically concepts which are presented in the theories. All of them thought that there is no difference between an object and a force exerted to an object, and empirical concepts could be seen while theoretical concepts could not. In addition, the students had the similar ideas about the scientific evidence and 96% of the participants viewed experiment is necessary for scientific proof. The view that theories change but laws not change (95%) was also prevalent among the preservice teachers.

Şahin, Deniz, and Görgen (2006) conducted a study aiming to investigate both secondary school social and science branch post-graduate (non-thesis master) teacher candidates views about the NOS. A 12-item Likert type scale was administered to 207 participants. A score of 1 assigned to answers to the items indicated a low acceptance of related NOS aspect, while a score of 5 assigned to answers to items indicated a high acceptance. The student teachers generally showed a low level of understanding of the NOS. Characteristics of science particularly was not well understood including the independence of scientific knowledge from religious affirmation (%32), direct observation (%37), and the limits of science (%30). The characteristics of science which was well understood by the student teachers were the goals of science (%84), scientific theories (%82), scientific experiments (%69), and the inability of science to address ultimate causation (%84).

During the development and initial implementation of a NOS rubric by Brown, Luft, Roehrig, and Kern (2006), beginning science teachers' perspectives on NOS was investigated. The creation of the rubric involved five beginning secondary science teachers, four experienced secondary science teachers, and five additional beginning secondary science teachers used to pilot the rubric. Three different perspectives of NOS labeled as "Product", "Process", and "Situated," with the "Situated" category aligning to a more tentative view of science. Initial findings showed that most beginning teachers conceptualized NOS using "Product" and/or "Process" frameworks, and displayed a naive understanding of the relationship between theories and laws. Experienced teachers who have taken a NOS course aligned their NOS perspective with “Situated” perspective.

Liu and Lederman (2007) explored the relationship between 54 Taiwanase prospective science teacher’s culturally based worldviews and conceptions of NOS. Data were collected through Views on Nature of Science Form-C (VNOS-C) for teachers’ conceptions on NOS and five open ended questions for teachers’ worldviews. Understandings of NOS were classified into informed and naive categories based upon contemporary views of these constructs and those stressed in international reform documents. The majority of participants (over 70%) held inadequate views of the empirical NOS, tentativeness of scientific knowledge, creativity and imagination involved in scientific investigation, and hierarchical relationship between theories and laws. In addition, most of the participants viewed science as equivalent to technology or believed that scientific knowledge is proven true based on objective observations or experimental evidence (%64). About 40% of participants demonstrated adequate understandings of the distinction between observation and inference. Majority of the participants ascribed theory change solely to new information and technologies and many also believed that theories are tentative due to insufficient evidence for proving their validity (%59). All of the respondents held naive views that scientific laws can be proven true through repeated testing and scientific theories are tentative antecedents to scientific laws (%76). Almost all participants indicated that creativity and imagination are needed in the development of scientific knowledge placed different emphases on the only one stage of investigation (%57). Participants viewed scientific knowledge as universal and failed to recognize that different belief systems could influence the use of scientific knowledge and the way scientific investigations are conducted (%46).

Yalvaç et al. (2007) explored Turkish preservice science teachers’ views on science-technology-society issues. Data were collected through an adopted form of VOSTS instrument consisting of 26 multiple-choice items from176 pre-service science teachers who enrolled in three different science education programmes. Subscales of the instruments are as 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. Results of the study showed that Turkish pre-service science teachers held a realist view that scientific knowledge is subject to change (%76), interdependence of science and technology (%75), influence of society on science/technology (%61), influence of science/technology on society (%62), social construction of scientific knowledge (%76). While many pre-service science teachers viewed technology as the application of science (39%) and nearly all the participants agreed on the hierarchical relationship in which hypotheses become theories and theories become laws depending on the availability of the supporting evidence (%93).

Akerson et al. (2008) as a part of their investigation examined the relationship between pre-service teachers' NOS views, their ethical and intellectual positions, and cultural values. The Views of Nature of Science Form B (VNOS-B) to describe NOS views, the Learning Context Questionnaire (LCQ) to classify pre-service teachers' ethical and intellectual positions using Perry's scheme, and the Schwartz Values Inventory (SVI) were used to measure pre-service teachers' cultural values. Participants were all 14 early childhood pre-service teachers who were enrolled in The Early Childhood Education Teacher Education Program. Researchers coded elementary teachers' views as either ‘‘informed’’ (indicating a fully developed understanding of the NOS aspect), ‘‘adequate’’ (indicating a developing view), or ‘‘inadequate’’ (indicating a misconception was held by the student). Prior to instruction, none of the preservice teachers held adequate or informed views of the elements of NOS including empirical basis, observations and inferences, creativity and imagination, social and cultural embeddedness, scientific theories and laws, and multiple methods of scientific investigations.

In a recent study conducted by Liang et al. (2008), an instrument was developed to evaluate NOS views of preservice teachers. Utilizing convenience sampling technique, the study involved 209 preservice elementary teachers who were enrolled at two American universities. The participants were either majoring in elementary education (K-6) or had dual majors in elementary (K-6) and special education (K-12).The target NOS ideas reflected in the instrument are tentativeness, empirical basis, observations and inferences, creativity and imagination, social and cultural embeddedness, scientific theories and laws, and multiple methods of scientific investigations. The instrument comprising of 58 Likert scale items and 10 open-ended questions was developed considering empirically derived instruments such as VOSTS and students' responses on VNOS. By using this instrument, researchers stated that most of the pre-service elementary teachers hold naive conceptions on several NOS aspects including creativity and imagination (%42), scientific theories and laws (%98), and multiple methods of scientific investigations (%33).

Aslan (2009) investigated 74 science teachers' views of NOS. The researcher used an 18-item questionnaire which was modified using the items of VOSTS. The analysis revealed that science teachers had naive conceptions on various NOS aspects including definition of science (5,5%), effect of science on society (33,9%), features of scientists (32,5%), nature of observations (41,6%), scientific models (69%), nature of classification (21,6%), tentativeness of scientific knowledge (25,8%), the relationship between hypothesis, theory, and law (97,3%), scientific assumptions (45,9%), theories (33,9%), the scientific method (37,8%), scientific laws (79,8%), scientific hypothesis (74,3%)

In a recent study Ayvaci and Er Nas (2010) investigated 26 in-service science teachers' understanding of NOS using seven open ended questions. The results of this study revealed that science teachers had naive understandings on several NOS aspects. The percentages of teachers having naive NOS conceptions are as below;

- The purpose of science is to achieve abstract truth (27%)
- Scientific knowledge is absolute where the knowledge in other fields is not (27%)
- Experiments are crucial to reach scientific knowledge (50%)
- With the proof theories become laws (15%)
- Theories can change while laws cannot (54%)
- The role of creativity and imagination is less than the scientific method itself (23%)

Doğan et al. (2011) as a part of their study firstly identified the participants' NOS understandings using a 14-item questionnaire which was formed using the items of VOSTS questionnaire. Analysis of pre-test results showed that teachers had naive conceptions on various NOS aspects including scientific models (48.7%), the relationship between hypotheses, theory, and law (86.4%), nature of theories (74.4%), the scientific method (38.6%), epistemological status of theory (47.6), law (66.7%), and hypothesis (70%).

The aforementioned studies provided an empirical evidence for both pre-service and in-service science teachers' inadequate NOS understandings irrespective from the instruments used to assess NOS. These findings indicate the necessity of helping teachers to increase their understanding of NOS. PCK for NOS instruction designed in this study, firstly, aimed to enhance pre-service chemistry teachers' NOS conceptions and hence fulfilled the gap in literature advocating the need for educating teachers for NOS. In addition, since teachers' NOS conceptions in this study is a prerequisite for a well-developed PCK for NOS and at the same time, the instruction was helpful for teachers to satisfy the necessary condition for a well established PCK for NOS. The next step is to find out whether teachers with adequate NOS understanding successfully translate their NOS conceptions into their classroom and the factors that facilitate or impede this translation.

2.3. Factors Affecting Teachers' Translation of Their NOS Understanding into Classroom

Empirical studies revealed that both pre-service and in-service science teachers do not have adequate NOS understandings. As an attempt to solve this problem, science educators directed their attention to various attempts for improving teachers' inadequate understandings of NOS. The efforts emerged as implicit and explicit approaches to NOS instruction (Abd- El-Khalick & Lederman, 2000a).

The basic assumption of implicit approach is that learning about NOS would occur as a consequence of the learners' engagement in science-based activities without any direct references to NOS. Therefore, successful experiences in doing science such as science process-skills instruction or engagement in science-based inquiry activities stimulate acquiring of better conception on NOS. Contrary to the implicit approach, advocates of an explicit approach contended that enhancing learners' conceptions of NOS should be planned for instead of solely having students participated in science activities. In addition, they claimed that certain aspects of

NOS should be made explicit in any attempt aimed at fostering adequate conceptions of NOS among learners. Therefore, those researchers provided opportunities for students where they reflect on their experiences explicitly in a way to relate science with their experiences. The basic difference between implicit and explicit approaches is not the kind of activities used to promote NOS understandings. The difference is the extent to which learners are provided with the conceptual tools that would enable them to think about and reflect on the activities in which they are engaged. As a result of their review of the empirical studies Abd-El-Khalick and Lederman (2000a) concluded that explicit approach was more effective in development appropriate conceptions of NOS among science teachers.

With the recognition of success of explicit-reflective approach in improving teachers' NOS conceptions, the number of studies using that approach started to increase (Akerson et al., 2000; Abd-El-Khalick & Lederman, 2000b; Lin & Chen, 2002). In addition, assumption that there is a clear-cut relationship between teachers' NOS understanding and successful translation of their NOS conceptions into classroom practice also accelerated the studies on NOS. Researchers tried to explore whether teachers with adequate NOS conceptions are good at translating their understanding into classroom practice and if not to reveal the factors that impede this relationship.

One of the earlier attempts, exploring the relationship between teachers' beliefs about NOS and their classroom practice, was made by Brickhouse (1990). She conducted her study with three science teachers using interviews, observations, and classroom artifacts in order to reveal their beliefs about NOS and science teaching. The results of this study indicated that teachers may reflect their beliefs about the nature of scientific theories, scientific process, and progress in their classroom instruction. While two experienced science teachers' consistent practice provided evidence for the coherence between their NOS beliefs and teaching practice, the beginning teacher's instruction varied from day to day and did not reflect his NOS beliefs. The beginning science teacher's practice was an evidence for the absence of clear-cut relationship between teachers' NOS understanding and teaching.

As a follow up study, Brickhouse and Bodner (1992) focused on the beginning teacher's beliefs about science and science teaching for elucidating the factors resulting in incongruence between her beliefs and practice. They conducted a seven-month length case study. Interviews, classroom observations, and documents related to teaching were used as data collection sources. Data sources pointed out several factors that impeded this beginning teacher's successful translation of his NOS understanding into classroom as institutional constraints including pressure to teach school science instead of NOS, classroom constraints including students' concern for grades and lack of SMK, institutional constraints including impact of principals, regulations and social hierarchies, scheduling of classes, building designs, and texts and materials for instruction.

After these studies science education community shifted their attention to how teachers' classroom instruction may or may not reflect their NOS understandings and the reasons explaining it. In the following year, Hodson (1993) investigated the degree to which teachers' design and choice of learning activities reflect their NOS views. Firstly Hodson identified teachers' philosophical stands toward science and categorized seven teachers as inductivist who emphasizes the priority of observation (2), hypothetico-deductivist who gives priority to theory and emphasizes falsification by critical experimentation (3), and contextual advocating who believes that there is no one method of science (2). Observations, teaching materials, and interviews supported the finding that teachers do not directly translate their NOS conceptions into classrooms. Although only two teachers had inductivist stance, inductivist and verificationist laboratory experiences were dominant in their classrooms. Teachers expressed several constraints for the inconsistencies between their philosophical stance and classroom practice as lack of time and resources, pressure of the curriculum and exams, laboratory management and organization issues, concerns about discipline, and organizing and selecting the most appropriate experiments that work for both content and in class.

After realizing that there was no clear-cut relationship between teachers' NOS understanding and their classroom practice (Brickhouse, 1990; Brickhouse & Bodner, 1992; Hodson, 1993), science educators started to seek for addressing the difficulties that teachers faced with when teaching NOS. With this purpose, Abd-El-

Khalick et al. (1998) designed a program for secondary science teachers in which they taught NOS in an explicit-reflective manner. They investigated the effectiveness of this program on secondary science teachers' NOS understanding and teaching practices using various data sources including VNOS and associated interviews, daily lesson plans, classroom videotapes, supervisor's notes, and portfolios including rationales, goals, objectives, lesson plans, assessment instruments, reflections. Although teachers (n = 14) possessed adequate understandings on numerous NOS aspects after participation to the program, they were not able to translate their NOS understandings into classroom even though they thought that they did so. Teachers' lesson plans and instructions provided little evidence for explicit references to NOS. Moreover, teachers stated several factors for inadequacy of their lesson plan and instruction for teaching NOS such as not seeing NOS as much significant as other learning outcomes (e.g., science content), classroom management concerns, insufficient NOS understanding, lack of resources and experience for NOS teaching, time limitation, and constraints forced by cooperating teacher. Abd-El-Khalick and his colleagues recommended that teachers should be provided with the opportunities where they experience teaching and assessing NOS. Also, the need for programs where learning NOS and learning how to teach NOS part are separated from each other was evident in their suggestions.

As a response to Abd-El-Khalick et al.'s (1998) call for programs, where learning NOS and learning how to teach NOS are separated, Lederman (1999) conducted a multiple-case study with five biology teachers (3 males and 2 females) possessing different teaching experiences (two beginning and three experienced) in a series of workshops intended to teach both NOS and how to teach NOS. After completion of the workshop, semi-structured interviews, an open-ended questionnaire, classroom observations, lesson plans, instructional materials, periodic informal interviews/discussions, and student interviews were used during a year-long case study. Analysis of data revealed that teachers' NOS conceptions did not directly influence their classroom practice. Teaching experience, on the other hand, was an important factor in teaching NOS because experienced teachers' classroom practice indicated a consistency with their views of NOS, which is similar to the findings of Brickhouse (1990). Another important factor was teachers' beliefs in the importance of NOS as a learning outcome as indicated by Abd-El-Khalick et al. (1998) and intentions to teach NOS. Unless teachers believe in the importance of NOS they do not teach NOS in their classroom. While classroom management concerns was reported by beginning teachers as a concern for not teaching NOS, experienced teachers stated lack of experience in NOS teaching as a factor. Interestingly, curriculum was not found to be as a factor that prevents teachers to teach NOS since curriculum provided flexibility to teachers for teaching their own purpose. Lederman recommended that programs should include the components that help teachers in valuing NOS as an instructional outcome.

One year later after Lederman’s (1999) recommendation, Bell et al. (2000) included the valuing NOS component in the second one of a two consecutive science method courses. Eleven pre-service teachers learned NOS in an explicit-reflective manner in the first course and the second course included a student teaching experience component, emphasizing the difference between NOS and scientific inquiry, considering NOS as an important learning outcome, and inadequacy of implicit approach for teaching NOS. Various qualitative data sources were used including student teachers’ responses to VNOS questionnaire and interviews, daily lesson plans, classroom videotapes, supervisors’ observational notes, participants’ portfolio consisting of rationales, goals, objectives, lesson plans, assessment instruments, and videotapes of classroom instruction, and semi-structured interviews. Analysis of data indicated that most of the participants did not confuse NOS with science processes. Moreover, nine of the 11 pre-service teachers made explicit attempts to teach NOS in their class as evidenced by their lesson plans, portfolios, and supervisors' field notes. However, most of them failed to include an instructional objective about NOS that they intended to communicate during their teaching. A few NOS related objectives were found in their lesson plans but just two of them could be categorized as adequate. Also, pre-service teachers did not include NOS understanding as an important dimension to assess in their lesson plans and NOS teachings. Although participants recorded improvements in teaching NOS, they faced with several constraints namely conflict between teaching NOS and science content, lack of necessary time for NOS teaching and concern for falling behind the other teachers who are not teaching NOS, inadequate NOS SMK, lack of NOS teaching experience, lack of opportunity for deciding what to teach because of mentor teachers, and stress caused by student teaching, which leaded to failing to consider what is important to teach.

Although the importance of beliefs and intentions to teach NOS has been emphasized so far (Bell et al., 2000; Lederman, 1999; Lederman et al., 2001), Akerson and Abd-El-Khalick (2003) investigated whether these factors were sufficient in effective translation of NOS understanding into classroom during an experienced science teacher's, who had informed NOS understanding and intentions to teach NOS, NOS teaching in his class. Results showed that beliefs and intentions are necessary but not sufficient for an effective NOS teaching. Akerson and Abd-El-Khalick (2003) concluded their study with the need for professional development that stimulates the development of teachers' PCK for NOS. Similarly, Schwartz and Lederman (2002) investigated two beginning science teachers' knowledge, intention, and instruction planning after they participated to a program providing explicit-reflective NOS learning experiences, requiring inclusion of NOS in instructional objectives and assessments. That is, teachers were externally forced to intend to teach, include NOS related objectives, and assess NOS in their NOS teaching attempts. Their initial attempts for teaching NOS were not complete and proper considering the content they taught while their following attempts were more successful. Requiring extra effort, lack of NOS understanding and discipline specific SMK, the relationship between NOS and science subject were the factors found to be influencing in teachers' learning and teaching NOS, which was an evidence for insufficiency of intentions for teaching NOS. Schwartz and Lederman (2002) advocated that teachers should possess PCK for NOS for effectively translating their understandings into classrooms and there was a need for meaningful professional development enhancing teachers' PCK for NOS.

Lederman et al. (2001) concentrated their efforts on finding out facilitating and inhibiting factors in teaching NOS. Seven pre-service teachers who participated in a program on teaching and learning NOS through activities constituted the cases of this study. VNOS in conjunction with interviews, lesson plans, classroom observations, formal and informal discussions, and exit interviews provided evidence for facilitating and inhibiting factors. As facilitating factors, researcher support, NOS course and activity packet, intentions to teach NOS, and viewing NOS consistent with curriculum came into prominence while classroom management, time constraints, lack of NOS knowledge, SMK, state standards, lack of ownership of practicum class, and general pedagogical concerns were found to be inhibiting ones. When these factors were compiled into more general categorizations intentions for teaching NOS, NOS knowledge, SMK, and pedagogical knowledge (PK) were described as the most influential factors. Lederman and colleagues (2001) recommended that one must avoid providing a list of NOS teaching activities if s/he intends to empower teachers' PCK for NOS and there is a need for that kind of meaningful professional development programs.

Different than the majority of the studies focusing on factors affecting translation of teachers' NOS understandings into classroom through the use of qualitative methods, Sweeney (2010) used survey research in order to determine the factors (importance, developmental appropriateness, and presence of NOS aspects in state standards) predicting teachers' teaching of NOS in their classrooms. Twelve-item questionnaire including Likert-type questions scored on a 5-point scale was administered to 377 K-4 teachers. Different factors were found to be significantly predictive in determining the teaching of different NOS aspects. Developmental appropriateness was found to be a significant predictor of teachers' teaching all the NOS aspects but collaborative, empirical, and inferential. Seeing NOS as an important learning outcome was a significant predictor for all NOS aspects. Teaching the creative and absence of step by step scientific method NOS aspects were predicted by presence in state standards but not by the other NOS aspects.

Beginning from Brickhouse (1990) and followed by other science educators (Abd-El-Khalick & Akerson, 2003; Abd-El-Khalick et al., 1998; Brickhouse, 1990; Brickhouse & Bodner, 1992; Lederman, 1999; Lederman et al., 2001; Schwartz & Lederman, 2002), research on investigating the factors that influence teachers' translation of their NOS conceptions into classroom practice indicated some regularity with regard to research design, data collection sources, and more importantly factors. In the light of these findings in the literature, the factors influencing teachers' translation of their NOS understanding into classroom practice can be summarized as;

- Teachers' beliefs and intentions (Abd-El-Khalick & Akerson, 2003; Bell et al., 2001; Herman, 2010; Lederman, 1999; Lederman et al., 2001; Sweeney, 2010)
- Classroom management (Abd-El- Khalick et al.,1998; Hodson, 1993; Lederman, 1999; Lederman et al., 2001; Ochanji, 2003)
- Pressure to cover science content covered in curriculum (Aslan, 2009; Brickhouse & Bodner, 1992; Hodson, 1993; Lederman et al., 2001; Ochanji, 2003; Koehler, 2006)
- Pressure from co-operating teachers and parents (Abd-El-Khalick et al., 1998; Aslan, 2009; Bell et al., 2000; Koehler, 2006; Ochanji 2003)
- Lack of SMK (Brickhouse & Bodner, 1992; Hodson, 1993; Lederman et al., 2001; Schwartz & Lederman, 2002; Wahbeh, 2009)
- Inadequate NOS understanding (Abd-El-Khalick et al., 1998; Akerson et al., 2009; Bell et al., 2000; Lederman, 1999; Lederman et al., 2001; Ochanji, 2003; Schwartz & Lederman, 2002)
- Time restrictions (Abd-El-Khalick et al., 1998; Bell et al., 2000; Brickhouse & Bodner, 1992; Hodson, 1993; Koehler, 2006)
- Absence of resources and experience for teaching NOS (Abd-El-Khalick et al., 1998; Akerson et al., 2010; Bell et al., 2000; Brickhouse & Bodner, 1992; Hodson, 1993; Lederman, 1999; Lederman et al., 2001; Wahbeh, 2009)
- Confusing NOS with scientific inquiry (Bell et al., 2000; Koehler, 2006; Ochanji 2003)
- Concern for students' abilities to learn NOS (Koehler, 2006; Sweeney, 2010)
- Undeveloped PCK for NOS (Abd-El-Khalick & Lederman, 2000a; Akerson & Volrich, 2006; Hanuscin et al., 2011; Lederman et al., 2001; Ochanji, 2003; Schwartz & Lederman, 2002; Wahbeh, 2009)
- Feeling responsibility for teaching NOS (Herman, 2010)
- Low self-efficacy for teaching NOS (Akerson et al., 2009; Schwartz & Lederman, 2002)
- Presence of state wide tests (Aslan, 2009; Brickhouse & Bodner, 1992; Koehler, 2006)

- Absence of NOS in curriculum to be followed (Akerson et al., 2009; Akerson et al., 2010; Koehler, 2006; Lederman et al., 2001)

Various factors have been well documented for teachers' unsuccessful NOS teaching practices and PCK for NOS is one of them affecting teachers' use of NOS in their instruction. Science educators might help both pre-service and in-service teachers by designing courses and trainings that stimulate the development of PCK. The need for designing professional development programs that help teachers to develop and revise existing materials and enable them to develop PCK for NOS considering all sub-dimensions namely STO, KoL, KoIS, KoA, and KoC has been well documented in literature (e.g., Akerson & Abd-El-Khalick, 2003; Akerson &Volrich, 2006; Hanuscin & Hian, 2009; Hanuscin et al., 2011; Schwartz & Lederman, 2002). In addition, the area of PCK for NOS requires more studies (Lederman et al., 2001), especially the ones using an explicit PCK framework (e.g., Magnusson et al., 1999). This study fills the gap in literature by both using a particular PCK framework (Magnusson et al., 1999) and designing a program that enhances the development of PCK for NOS. Before explication of PCK for NOS, we should clearly define what PCK is.

2.4. Pedagogical Content Knowledge

PCK is the knowledge that differentiates a scientist from a science teacher (NRC, 1996) and known as pedagogical professional knowledge for teachers. The PCK was first conceptualized by Shulman (1986) as a result of his research on the way in which a college graduate transforms his/her SMK into a form which is understandable by students. Shulman (1986) focused on "Knowledge Growth in Teaching" and sought for the answers of "What are the sources of teacher knowledge? What does a teacher know and when did he or she come to know it? How is new knowledge acquired, old knowledge retrieved, and both combined to form a new knowledge base?" (p. 8). He came up with three type of content knowledge and differentiated among three which are SMK, curricular knowledge, and PCK. SMK is defined as consisting of substantive and syntactic knowledge. Substantive knowledge refers to basic principles and concepts of the discipline that form the accepted truths in a domain to be communicated to students while syntactic knowledge refers to principles and means by which knowledge in a discipline develops and accepted (e.g., NOS for science). Curricular knowledge was teachers' knowledge on existent program that can be used for teaching specific subject and topic, accompanying instructional materials, how the topic being taught is related to other topics that students learn at the same time (lateral curriculum), and topics in the preceding and following years that are correlated to the topic of instruction (vertical curriculum). PCK was defined as

> ….knowledge, which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching...Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations-in a word, the ways of representing and formulating the subject that make it comprehensible to others. …[PCK] includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons (p. 8).

In the following year, Shulman (1987) pursued his research on knowledge base for teaching and sought for the answers of sources of the knowledge base for teaching, the terms used for conceptualizing these sources, and implications for educational reform and teaching policy. He came up with the following list of teacher knowledge ensuring students' comprehension of a topic:

> content knowledge; general PK, with special reference to those broad principles and strategies of classroom management and organization that appear to transcend subject matter; curriculum knowledge; with particular grasp of the materials and programs that serve as the "tools of trade" for teachers; pedagogical content knowledge, that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding; knowledge of learners and their characteristics; knowledge of educational contexts, ranging from the working of the group or classroom, the governance and financing of school districts, to the character of

> communities and cultures; and knowledge of educational ends, purposes, and values, and their philosophical and historical grounds (p. 8).

Moreover, Shulman (1987) made an attempt for describing the process in which teachers transform their SMK in a way that is comprehensible and understandable by students (see table 3). He added that the steps constituting the process were not fixed and rather were changeable as teachers' ability and grade level changed. Shulman (1987) concluded that there was a need for teacher assessment and education programs grounded on content embedded pedagogy, which is PCK.

Table 3. A Model of pedagogical reasoning and action from Shulman (1987, p. 15)

Reasoning	**Action**
Comprehension	SMK about and outside of the discipline
Transformation	Preparation of an instructional repertoire and clarification of instructional purposes
	Representation selection including analogies, metaphors, demonstrations, examples, explanations and etc.
	Selection from instructional repertoire
	Adaptation and tailoring to student characteristics
Instruction	Observable forms of classroom teaching
Evaluation	Checking for students' understanding and teaching performance
Reflection	Reviewing and critically analyzing one's own teaching
New	On SMK, students, teaching, self
Comprehension	Reinforcing of new understandings, and learning from experience

After the work of Shulman (1987), Tamir (1988) elaborated and extended the notion of PCK providing a framework for defining teachers' knowledge base. That framework included six categories which were general liberal education (basic skills of reading, mathematics, comprehension, and reasoning), personal performance, subject matter (knowledge and skills in related domain), general pedagogical (student, curriculum, instruction, and evaluation), foundations of the teaching profession (history and policy, philosophy and psychology, cultural and cross-cultural factors, professional ethics), and subject matter specific pedagogical, which is PCK. Tamir (1988) made a clear distinction between PK and subject matter specific PK by stating that

> This distinction is very important with regard to teacher education. Since, while the first (i.e. general pedagogy) may be handled by experts in general pedagogy and, hence, can be taught in mixed disciplinary classes, the second (i.e., subject matter specific PK) must be handled by instructors who are pedagogical experts in a particular discipline working with student teachers preparing to teach in that discipline (p. 100).

Moreover, Tamir (1988) elaborated Shulman's (1986) idea of PCK including the following components:

- Student: Knowledge (Specific common conceptions and misconceptions in a given topic), skills (How to diagnose a student conceptual difficulty in a given topic)
- Curriculum: Knowledge (The pre-requisite concepts needed for understanding a specific topic in science), skills (How to design an inquiry oriented laboratory lesson)
- lnstruction (Teaching and management): Knowledge (A laboratory lesson consists of three phases: pre-lab discussion, performance, and post-laboratory discussion), skills (How to teach students to use a microscope)
- Evaluation: Knowledge (The nature and composition of the Practical Tests Assessment Inventory), skills (How to evaluate manipulation laboratory skills)

The most distinguishable feature of Tamir's (1988) model of PCK from Shulman's (1986; 1987) is the inclusion of assessment as a dimension of PCK and differentiating between knowledge and skill by defining each for all the PCK components.

Grossman (1990) investigated the nature and sources of PCK utilizing the data she obtained from three beginning English teachers with no professional preparation and three graduates of a five-year teacher education program. She proposed a model of teacher knowledge and advocated that there were four areas which form the base of professional knowledge for teaching; general PK, SMK, PCK, and knowledge of context (KoCx) (see Figure 1).

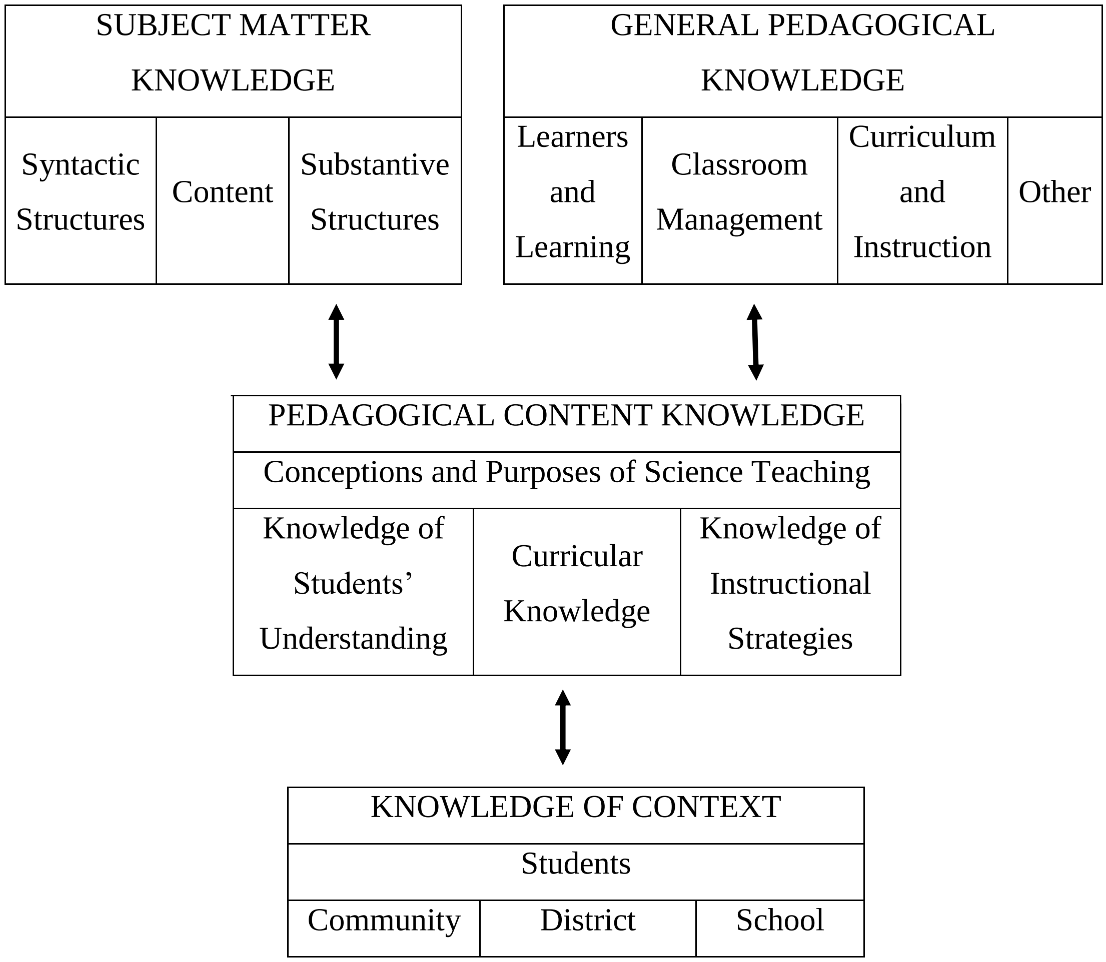

Figure 1. Model of teacher knowledge (Grossman, 1990, p. 5)

Grossman's (1990) model suggests that there is a reciprocal interaction between SMK, PK, KoCx, and PCK. Although it is clear from the Shulman's (1986; 1987) PCK definitions that KoIS for teaching particular topics and KoL, are the two key components of PCK, Grossman (1990) added two more on these components as conceptions and purposes of teaching science and curricular knowledge which was an separate base from PCK ensuring translation of SMK into a comprehensible from by students. While the former refers to teachers' knowledge and beliefs about the purposes for teaching a subject at different grade level, the latter refers to the knowledge on available curriculum materials for teaching particular topic and what students studied in the past and will study in the future in the same grade (horizontal) and previous or next grade (vertical). However, Grossman did not mention about assessment as a dimension of PCK although Tamir (1989) explicitly stated about that component. Moreover, Grossman (1990) argued that the aforementioned PCK components were not fragmented in practice as it was explained in theory. With regard to the sources, the study provided four different sources from which different PCK components develop: (a) disciplinary education for SMK, conceptions of teaching the discipline, KoC, and KoIS, (b) observation of classes for KoC, KoL, and KoIS, (c) classroom teaching experiences for KoIS and KoL, and (d) teacher education courses for conceptions of teaching the discipline and KoIS curriculum.

Cochran, King, and DeRuiter (1991) brought a criticism as being static to the PCK definitions in literature and defined PCK from a constructivist perspective as

> Pedagogical content knowledge is an integrated understanding that is synthesized from teacher knowledge of pedagogy, subject matter content, student characteristic, and the environmental context of learning. In other words, PCK is the using the understanding of subject matter concepts, learning processes, and strategies for teaching the specific content of a discipline in a way that enables students to construct their own knowledge effectively in an given context (pp. 11-12).

They advocated that the four components were transformed into PCK and PCK was the integration of four components which could not be observed as separate components. Later, Cochran, DeRuiter, and King (1993) used a new term "Pedagogical Content Knowing (PCKg)" for their constructivist-based PCK definition emphasizing dynamic nature. For them, development of PCKg is continual and PCKg enables teachers to create learning environments where students construct their own understanding with respect to specific topics. Moreover, Cochran et al. (1993) acknowledged that they added two new components to Shulman's (1986, 1987) PCK model as teachers' understanding of students including their abilities, ages, developmental levels, motivations, learning strategies, and prior conceptions and teachers' understanding of the social, political, cultural, and physical environmental contexts. They claimed that these two additional PCKg components formed the basis of constructivist based teaching since learning was created by students in social settings.

PCK definitions in literature summarized so far (Cochran et al., 1991; Grossman, 1990; Shulman, 1986; 1987; Tamir, 1988) did not include any argument about how their definitions might be re-conceptualized with respect to particular domains. This tendency changed with the work of Magnusson et al. (1999). They viewed PCK as a transformation of SMK, PK, and KoCx and elaborated upon Grossman's (1990) and Tamir's (1988) PCK model while describing their own. Magnusson et al.'s (1999) model defines a PCK model for science teaching and includes five components with the addition of a new one "KoA" to Grossman's (1990) which are conceptions and purposes of science teaching (refers to orientations toward teaching science or STO in Magnusson et al. (1999)), KoIS, KoC, and KoL (see Figure 2).

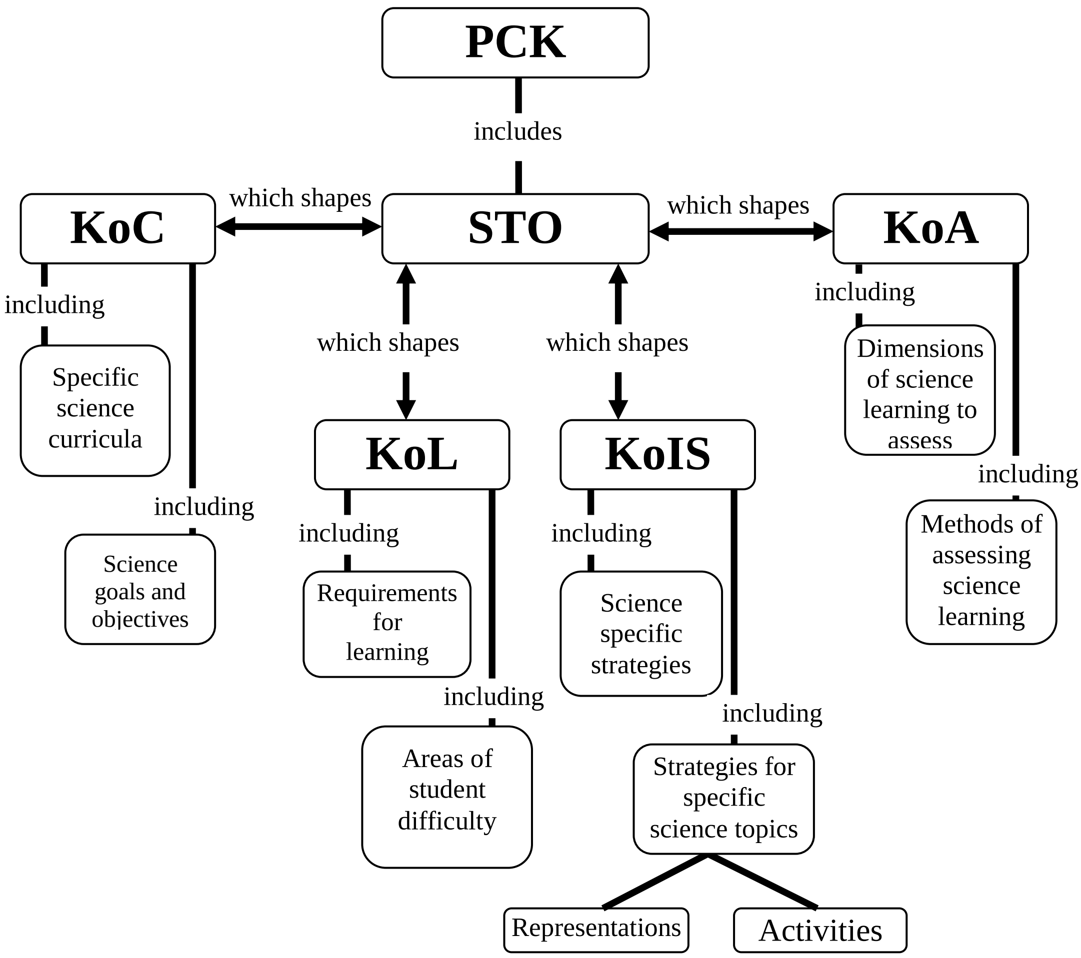

Figure 2. Magnusson et al.'s (1999, p. 99) PCK model for science teaching and its components

Explanation of each component in Magnusson et al.'s (1999) model is as follow;

1. STO was defined as teachers' beliefs and knowledge about their goals and purposes of teaching science at a particular level and directly influences teachers' decision making related to their instruction as it is obvious from the figure 2. There is a reciprocal relationship between STO and the other PCK components (KoC, KoL, KoIS, and KoA). Magnusson et al. (1999) defined several STO and accompanying instructional strategy. For instance, a teacher with a didactic orientation presents information through lecturing or discussion, and students are expected to know the facts of science or a teacher with an inquiry orientation engages students in defining and investigating problems, drawing conclusions, and assessing the validity of conclusions. Magnusson and colleagues argued that teachers might use the same instructional strategies but the purpose of implementation it determines a teacher's orientation.
2. KoC includes two sub-components as mandated goals and objectives, and specific curricular programs. While the former refers to teachers' knowledge about the curricular goals and objectives in the topic they teach for and the vertical curriculum (what students have learned in previous year and what they are expected to learn in the next year in the same topic), the latter refers to teachers' knowledge about the curricular programs and materials appropriate for teaching a specific domain or topic.
3. KoL includes two sub-components as requirements of science learning and areas of student difficulty. The former refers to teachers' knowledge what pre-requisite knowledge, skills and abilities are needed for students to learn the target topic as well as students' learning style differences while the latter includes teachers' knowledge about the difficulties and misconceptions of students in a particular topic.
4. KoIS includes two sub-components as subject specific instructional strategies and topic specific strategies. Subject-specific strategies are the ones used for teaching science (e.g., conceptual change, inquiry, problem based learning). Teachers should know how to employ them in their class. Topic specific

strategies are the representations (e.g., illustrations, examples, models, or analogies) and activities (e.g., problems. demonstrations, simulations, investigations, or experiments) that help students to comprehend the specific topic and these strategies differ from topic to topic.

5. KoA includes two sub-components as teachers' knowledge on what to assess and how to assess it. What to assess refers to teachers' knowledge on learning outcomes that need to be assessed throughout or end of the instruction. For instance, a teacher with a process orientation assesses students' scientific process skills as well as their knowledge on the topic. How to assess is the teachers' knowledge on various assessment methods used for assessing what needs to be assessed.

Magnusson et al. (1999) concluded their study with several arguments about the nature of PCK. These arguments are as;

- ...components that are shown indicate that there are different types of subject-specific pedagogical knowledge that are used in teaching science. Within each component, teachers have specific knowledge differentiated by topic, although they might not have similarly elaborated knowledge in each topic area (p. 115).
- Successful teachers are expected to develop all PCK components in all the topics.
- There should be coherence among all the components and development of a single component is not sufficient for a change in teachers' practice.
- A teacher's PCK in a topic might be different from another teacher's PCK in the same topic and even a teacher might have different PCK in different topics.

All the efforts defining PCK mostly focused on what constitutes the PCK. Related to formation of PCK some argued that several knowledge bases were transformed into a new form of knowledge which is PCK (Shulman, 1987; Magnusson et al., 1999). However, Gess-Newsome (1999) brought a different perspective on this issue by recommending a continuum and transformative and integrative PCK constitutes the two extremes on this continuum (see Figure 3). According to integrative model PCK does not exist and teacher integrates SMK, PK, and KoCx during his/her teaching. Transformative one implies that PCK is the new knowledge formed as a result of transformation of SMK, PK, and KoCx. She used an analogy from chemistry to better explain the two models. Integrative model is like a mixture of which the components can be separated while transformative one is like a compound of which the components lost their initial properties. There should be fluid integration of all components in an expert teacher's practice from the integrative perspective and on the other hand, an expert teacher should possess PCK for all the topics in transformative model.

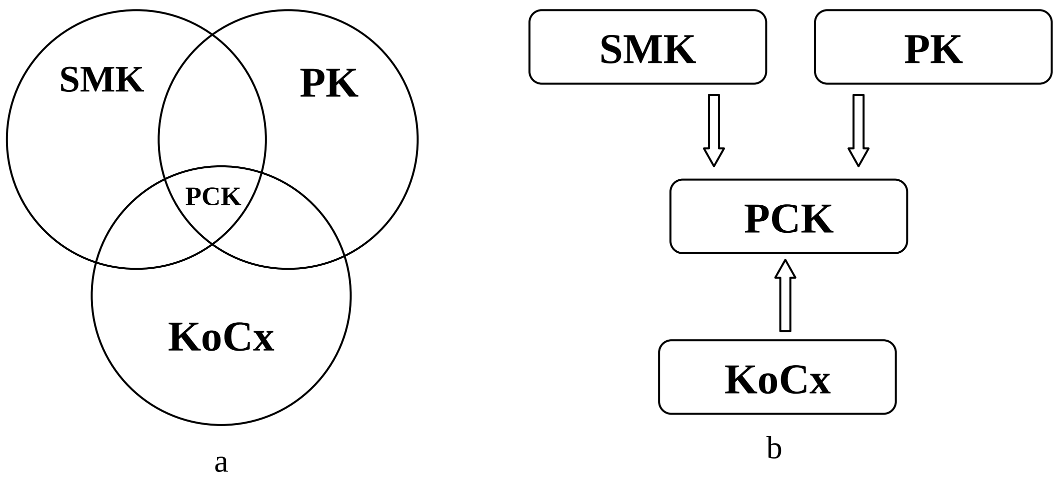

Figure 3. (a) Integrative model, (b) Transformative model (Gess-Newsome,1999, p. 12)

What have research claimed about the nature of PCK? Before the study of Veal and MaKinster (1999), there has been no explicit effort and consideration on this issue. There were several studies in which the nature of PCK was presented implicitly. For instance, Shulman (1986) advocated that there should be an examination of "…the subject and topic-specific pedagogical knowledge…" (p. 10) but did not provide any explanation about the difference between the two. Similarly, Magnusson et al. (1999) acknowledged that PCK

> ...components that are shown indicate that there are different types of subject-specific pedagogical knowledge that are used in teaching science. Within each component, teachers have specific knowledge differentiated by

topic, although they might not lave similarly elaborated knowledge in each topic area (p. 115).

Although both Shulman (1986) and Magnusson et al. (1999) mentioned about subject-specific and topic-specific pedagogical knowledge, they did not elaborate upon what they mean by these two. The first step in resolving the issue of nature of PCK was taken by Veal and MaKinster (1999). By utilizing from the literature, they came up with a scheme reflecting the hierarchical order among different PCK models beginning from general PCK and ending with topic-specific PCK (see Figure 4).

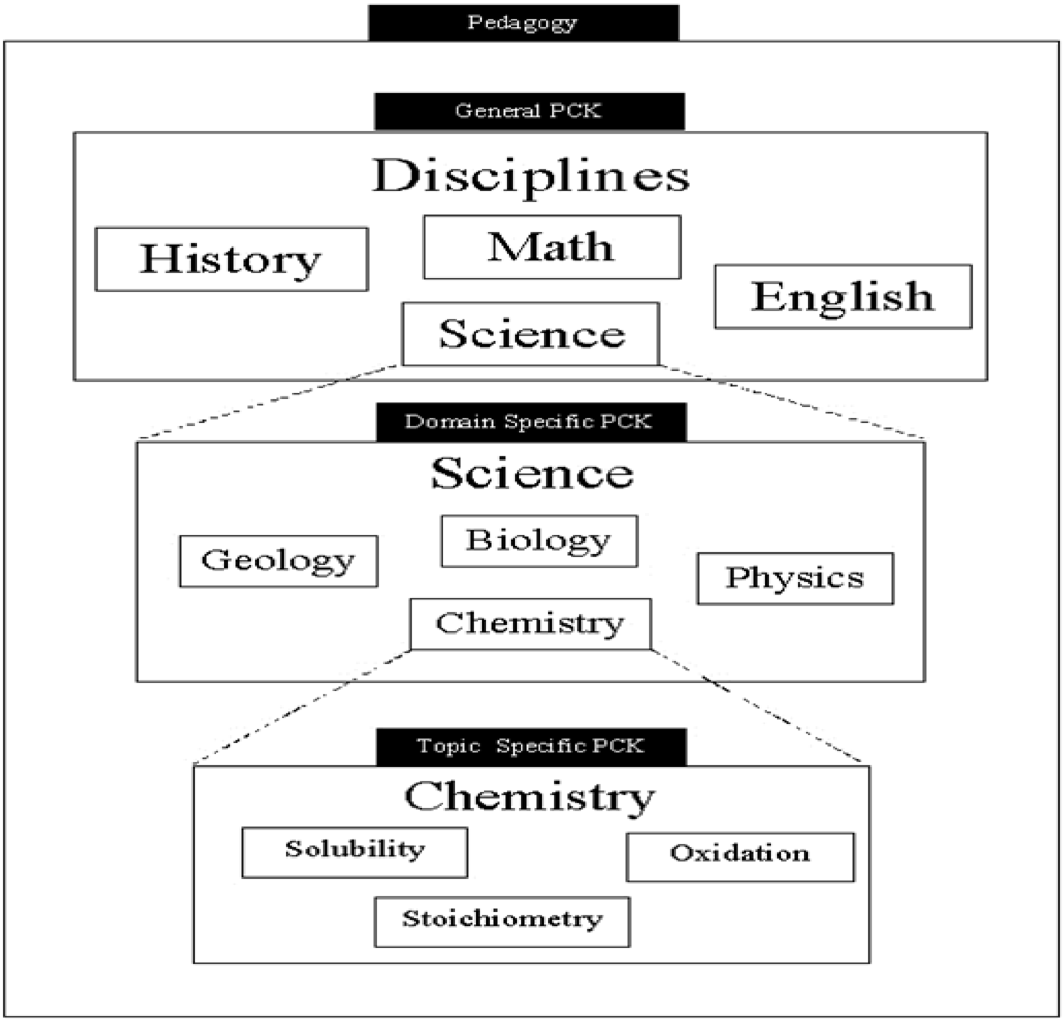

Figure 4. PCK Taxonomy proposed by Veal and MaKinster (1999)

Pedagogy is the broadest of all the PCKs and refers to knowledge on general teaching, assessment, evaluation, management, reinforcement, and etc. It is not specific to any discipline, domain, or topic and broadly applicable to all. General PCK was defined as the PCK relevant for different disciplines (e.g., science, mathematics, history). For instance, Magnusson et al. (1999) acknowledged that a science teacher should know teaching strategies specific to science such as learning cycle, problem-based learning, conceptual change, and etc. Different disciplines might use the same teaching strategy but the use and implementation of them are specific to the discipline. Domain-specific PCK is more specific than general one since it deals with the issues of teaching one of the domains (e.g., chemistry) in a discipline (e.g., science). There are variations in teaching strategies, laboratory activities, and assessment methods that are used by different disciplines in the same domain. But the purpose and tools are specific to the domain. Although the topic-specific PCK seems the most specific category among the others, a teacher who has this type of PCK could have the general, domain, and discipline-specific PCK. Veal and MaKinster (1999) argued that although there were some overlapping topics among different domains in science (e.g., heat and temperature), the representation of content in terms of the way and the degree indicates differences. For instance, while chemistry teachers prefer to use kinetic molecular theory, physics teachers prefer to use the concept of transferred heat when explaining the temperature. Topic-specific PCK implies that a teacher might have different PCK in different topics. Considering the differences in the nature, students' understandings, organization of the curriculum, teaching strategies, and assessment methods with respect to different topics it is expected that a teacher cannot have the same PCK across all topics s/he is teaching. For instance, a chemistry teacher's PCK in mole topic might be different from his/her PCK in chemical equilibrium topic.

After the work of Veal and MaKinster (1999), a few studies provided their arguments on the nature and types of PCK. Some researchers (Davis et al., 2008; Davis & Krajcik, 2005) advocated that teachers should possess discipline specific PCK as well as topic-specific one. They further explained that "[t]eachers must know how to help students understand the authentic activities of a discipline, the ways knowledge is developed in a particular field, and the beliefs that represent a sophisticated understanding of how the field works" (p. 5). Moreover, they claimed that a science teacher must have discipline-specific PCK and this PCK would allow him/her to engage his/her students in the process of scientific inquiry and more than that to help his/her students understand the scientific enterprise itself that is NOS. Similarly, Davis and colleagues (2008) defined PCK for scientific modeling as "… incorporates knowledge of instructional strategies that can promote students' engagement in modeling practices and learning of metamodeling knowledge. … also incorporates teachers' knowledge of their students' ideas and the challenges students face, again associated with modeling practices and metamodeling knowledge" (p. 6). Davis and Krajcik (2005) acknowledged that teachers should have all the components (KoIS, KoL, STO, KoA, and KoC) in their discipline-specific PCK.

PCK has been an important concern in education community especially among the ones interested in teacher education. Much effort has been placed on the components of PCK (Cochran et al., 1991; 1993; Grossman, 1990; Magnusson et al., 1999; Shuman, 1986; 1987; Tamir, 1988) while the nature and different types of PCK took less attention (Davis & Krajcik, 2005; Davis et al., 2008; Gess-Newsome; 1999; Veal & MaKinster, 1999). Since PCK for NOS is the concern for this study, one might ask which one can fully explain the nature and component of PCK for NOS and also which model can be used for research on explaining teachers' successful translation of NOS understanding into their classroom. In the following PCK for NOS part, I will seek for the answers given to this question and explain the PCK model that guided our study.

2.5. Pedagogical Content Knowledge for Nature of Science

PCK for NOS has been pointed out by science education community as one of the impeding factors affecting teachers' successful translation of their NOS understandings into their classroom (Abd-El-Khalick & Lederman, 2000a; Akerson & Volrich, 2006; Hanuscin et al., 2011; Lederman et al., 2001; Ochanji, 2003;Schwartz & Lederman, 2002; Wahbeh, 2009). Moreover, the task of designing professional development programs, helping teachers in developing and revising existing materials and enabling them to develop PCK for NOS considering all sub-dimensions namely STO, KoL, KoIS, KoA, and KOC, was assigned to science teacher educators (Akerson & Abd-El-Khalick, 2003; Akerson &Volrich, 2006; Hanuscin & Hian, 2009; Hanuscin et al., 2011; Schwartz & Lederman, 2002).

Lederman (1998) sees NOS as a topic in science and this shows the necessity for a conceptualization of PCK for NOS. When we apply the concept of PCK to NOS, it includes…

> … an adequate understanding of various aspects of NOS, knowledge of a wide range of related examples, activities, illustrations, explanations, demonstrations, and historical episodes. These components would enable the teacher 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 adapt those aspects to the diverse interests and abilities of learners (Abd-El-Khalick & Lederman, 2000, p. 692).

In other words, a teacher with a sufficient PCK for NOS is able to transform her knowledge about NOS into a form which ensures students' meaningful NOS learning. After this definition, in a study where Schwartz and Lederman (2002) investigated knowledge, intentions, and instructional practices of two beginning science teachers during their learning and teaching NOS, a model for PCK for NOS (see figure 5) and a model ensuring successful translation of NOS understanding into classroom practice were proposed.

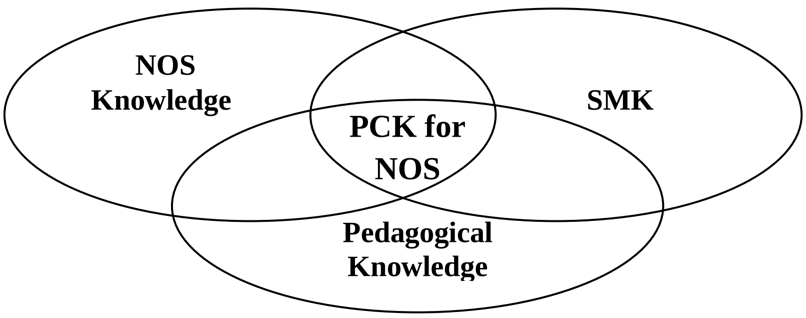

Figure 5. PCK for NOS (Schwartz & Lederman, 2002, p. 232)

Schwartz and Lederman (2002) conceptualized PCK for NOS as a blending of SMK, NOS knowledge, and PK. However, they did not elaborate how these individual components blend and form PCK for NOS. Moreover, how one can decide whether a science teacher has a well-developed PCK for NOS or not is not clear from their definition since the knowledge and skills of a teacher with PCK for NOS was not explicitly defined. Schwartz and Lederman emphasized that “For teachers to successfully address NOS, attention must be given to the development of “traditional” subject matter knowledge, NOS knowledge, and pedagogy *as well as* the interaction among these domains” (p. 232). With respect to PK, they addressed the necessity of knowledge of history of science (HOS), scientific inquiry, and related pedagogical approaches for teaching NOS. Although Schwartz and Lederman (2002) provided a little explanation about pedagogy, from their definitions it seems that they did not consider NOS assessment, students’ learning difficulties and misconceptions about NOS, and mandated NOS goals and objectives in their definition of pedagogy. On the other hand, they took attention to the necessity of further research on how SMK, NOS, and pedagogy contribute to emergence of PCK for NOS.

Schwartz and Lederman (2002) viewed PCK for NOS as necessary but not sufficient for ensuring teachers’ successful NOS teaching practices. Teachers’ beliefs and intentions are the other components that complement the PCK for NOS (see Figure 6). Beliefs were defined as teachers’ beliefs in their abilities to teach NOS (NOS teaching self-efficacy) and students’ ability to learn NOS (outcome expectancy). Intentions referred teachers’ setting teaching NOS as an instructional learning goal purposefully for themselves.

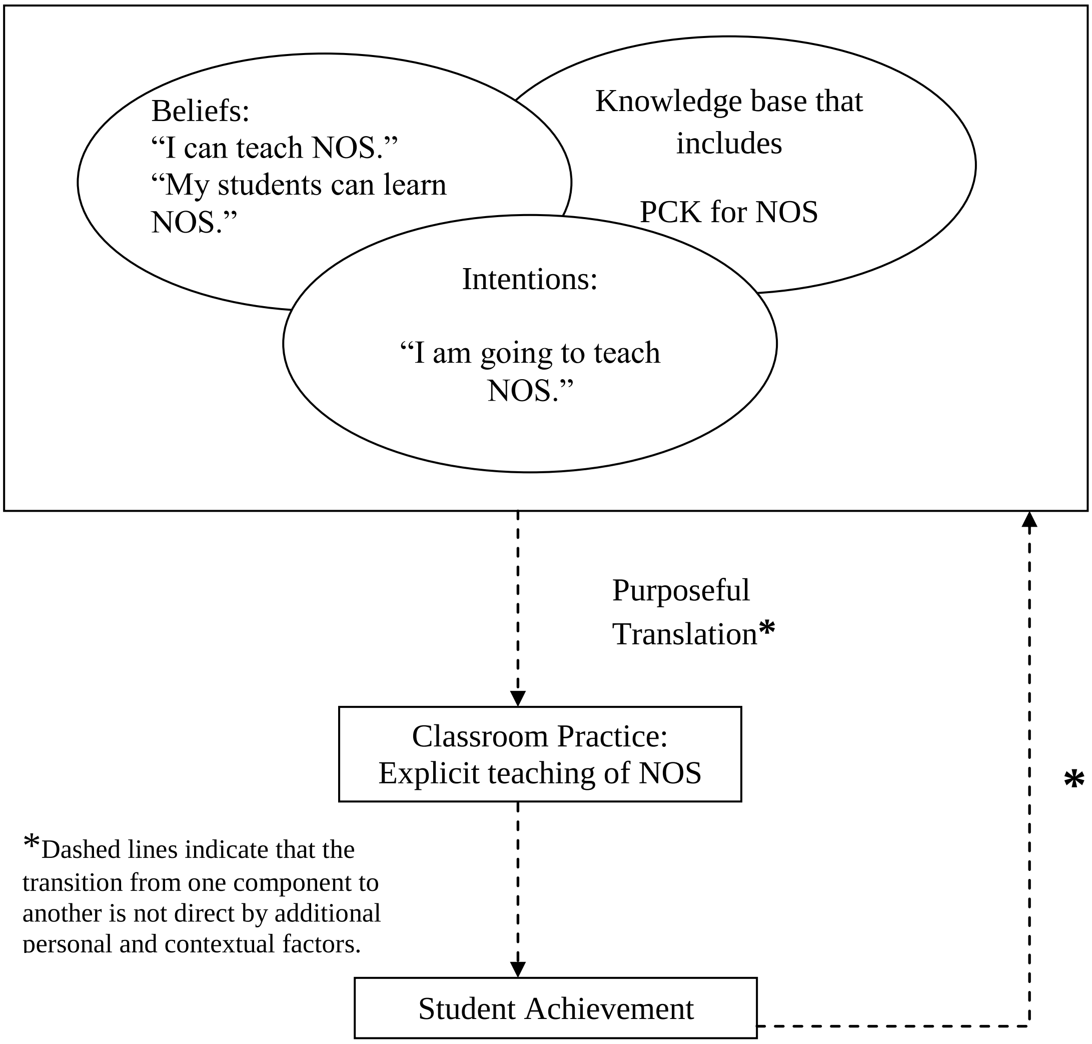

Figure 6. A model of the requirements for teaching NOS (Schwartz & Lederman, 2002, p. 233)

Kim et al. (2005) utilized a framework treating development of PCK for NOS as a continuum (Level 1-implicit, Level 2-didactic, and Level 3-explicit and reflective) in their attempt for investigating in-service teachers' pedagogical knowledge for teaching NOS throughout microteaching sessions. Ten participants had Level 1 PCK for NOS which means they included NOS objectives in their lesson plans but did not incorporate these objectives in their teaching. Twelve participants in Level 2 PCK for NOS addressed NOS in their teaching compared to Level 1 participants. However, these 12 participants preferred to make didactic explanation about NOS without explicit-reflective discussions right after completion of their teaching activity. Finally, 39 of 70 participants were categorized as Level 3 PCK for NOS and explicit-reflective NOS discussions together with assessment attempts were evident in their lesson plans. Kim et al. (2005) using the data of their own elaborated Schwartz and Lederman's (2002) PCK for NOS model. With regard to SMK, they emphasized the need for an understanding of scientific concept such as historical development of that concept and NOS-specific PK knowledge of the differences between an implicit and explicit approach and between a didactic and an explicit-reflective approach was necessary.

Utilizing the two PCK for NOS models proposed Schwartz and Lederman (2002), Jenny (2011) conducted a case study with five teachers in order to investigate their intentions to teach NOS, beliefs, and PCK for NOS. She categorized teachers' PCK for NOS into three as the beginning, developing, and experienced stages. Two of the teachers were in the beginning stage category and they focused on communication of NOS aspects by using the activities they learned from textbooks or teacher trainings without considering students' learning. One teacher in the developing stage designed their own instruction and considered students' difficulties and misconceptions about NOS. Two teachers in the experienced stage were able to design their own NOS teaching, revise existing materials for teaching NOS, and integrate NOS into their teaching even without purposefully plan to teach it. Moreover, these teachers considered students' needs, abilities, difficulties, and misconceptions more compared to the developmental stage teachers and collected continuous feedbacks on students' learning throughout their instruction. Jenny (2011) proposed the components essential for PCK for NOS as SMK, NOS knowledge, PK, knowledge of HOS, knowledge of students, knowledge of purpose of NOS attempts, and KoA and further emphasized the integration among these components for effective NOS instruction. Knowledge of students, knowledge of purpose of NOS attempts, and knowledge of assessment were the new components added to Schwartz and Lederman's (2002) model and integration was recognized by Jenny (2011) which was not mentioned by Schwartz and Lederman (2002). When a closer look was taken to the components proposed by Jenny (2011), the similarity between those components and Magnusson et al.'s (1999) components could be seen. For example, knowledge of students proposed by Jenny (2011) refers to KoL in the

Magnuson at al.'s model. In the same vein, knowledge of purpose of NOS attempts refers to STO, and knowledge of assessment is similar to KoA.

Different than the previous studies, some researchers preferred to use an already existing PCK models (e.g., Magnusson et al., 1999) by adapting it for NOS. Based on Magnusson et al.'s (1999) study claiming that their PCK model for science teaching is modifiable, Hanuscin and Hian (2009) and Hanuscin et al. (2011) used different contexts for investigating the PCK for NOS development; the former used mentor-mentee relationship and the latter used a professional development program where teachers learned about NOS and importance of NOS. First of all, both study supported the applicability of Magnusson et al.'s (1999) model as a lens for research on PCK for NOS. Also, the uneven development of PCK components (STO, KoIS, KoL, KoA, and KoC) was evident in their conclusions; that is, although mentee developed her KoIS for NOS, she did not develop KoL relevant to NOS (Hanuscin & Hian, 2009) and participants of professional development program developed KoIS but did not develop KoA (Hanuscin et al., 2011). Both studies emphasized that professional development efforts could be more effective by helping teachers to develop all PCK for NOS components instead of addressing some components. Also, the need for research on interplay among PCK for NOS components was highlighted (Hanuscin et al., 2011). A recent study (Faikhamta, 2012) responded that call and investigated in-service science teachers' NOS understanding and STO within a PCK-based NOS course. PCK-based NOS course was framed based on the PCK for NOS model adapted by Hanuscin et al. (2011) using Magnusson et al.'s PCK model. Throughout the course teachers' NOS understanding was addressed by explicit-reflective content-generic (e.g., mystery cube) and content-embedded activities (e.g., collision theories). Moreover, the course included some sessions on STO, KoIS, KoL, KoA, and KoC and analysis of the results showed that although in-service teachers had naïve and partially informed ideas about several NOS aspects (e.g., laws and theories, and tentativeness) before the course they improved their understanding into more informed views. With regard to change in STO that in-service teachers experienced, project-based science, process, and guided-inquiry were the most prevalent orientations considering the Magnusson et al.'s orientation categorization. After PCK-based NOS course, there were decreases in those orientations and the participants developed inquiry orientation. Although Faikhamta (2012) addressed all PCK for NOS components in the course, she did not analyze the all PCK components but STO and the integration among those.

Although the literature provides examples of several frameworks for investigating PCK for NOS, Pongsanon, Akerson, Rogers, and Weiland (2011) examined preservice teachers' PCK for NOS was shaped by collaborative planning, teaching, and reflective practice for which they called "lesson study." Pongsanon et al. (2011) mentioned about the degree of inclusion of NOS objectives in their planning and explicit attempts to teach NOS without considering student, assessment, and curriculum dimension.

In a recent study, Abd-El-Khalick (2012) decribed teacher knowledge domains for teaching with and about NOS and proposed a model including knowledge domains ensuring teachers' success in addressing NOS in their instructions. According to this model, NOS understanding, inquiry pedagogical skills and understanding, and science content understanding intersect to form PCK for NOS or what they called as NOS PCK. Moreover, the reciprocal interaction between any two of those requires teachers to have and enact those interactions in their teaching. Teachers' science content understandings refers to deep and integrated understandings of science content .Inquiry pedagogical skills and understanding includes two sub-dimensions as (a) enacting student-centered and inquiry teaching, and (b) appreciating, assessing, and monitoring changes in, students' conceptions of NOS The intersection between science content understanding and inquiry pedagogical skills and understanding.forms a new knowledge domain which is inquiry as instructional means. It deals with teacher understandings and skills related to teaching science content by using inquiry as an instructional method. The last dimension, NOS understanding, includes teachers' NOS conceptions approoriate to national reform documents. Moreover, it is not sufficient to ensure successful NOS teaching and three sub-domains of NOS understandings are needed. The first is understanding that NOS and inquiry are not the same while related and called as reciprocity of NOS and inquiry.The other sub-diemnsion of NOS understanding is is content-situated or domainspecific NOS understandings and refers to knowing which NOS conceptions are more germane to teaching within a specific topic (e.g., teaching nature of models in atom). This last dimension, HPSS, dimension is the knowledge of the historical, philosophical, psychological, and/or sociological aspects of the development of scientific knowledge.

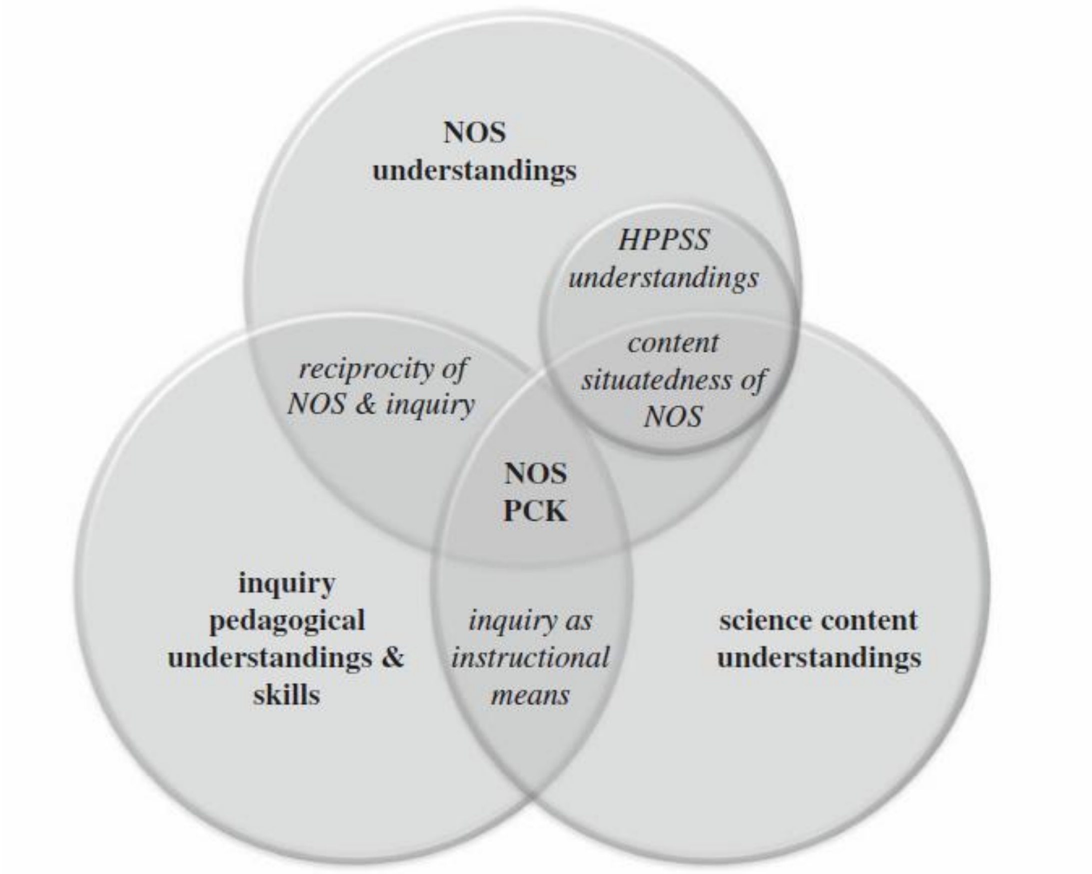

Figure 7. Teacher knowledge domains for teaching with and about NOS (Abd-El-Khalick, 2012)

To summarize, there are variety of studies on PCK for NOS; while some developed their own PCK for NOS model (Abd-El-Khalick, 2012; Jenny, 2011; Kim et al., 2005; Schwartz & Lederman, 2002), the others modified an already existing PCK model (Magnusson et al., 1999) for investigating PCK for NOS (Faikhamta, 2012; Hanuscin & Hian, 2009; Hanuscin et al., 2011), and few did not use a framework although they focused on PCK for NOS examination (Pongsanon et al., 2011). PCK for NOS models neither proposed nor modified by the researchers shared some common elements as KoL, KoA, KoIS, and STO. These components strengthened the Magnusson et al.'s (1999) model as a lens for research on NOS and this model guided our research in designing our PCK for NOS instruction and monitoring development of pre-service chemistry teachers' PCK for NOS.

Another important issue that needs to be considered is the nature of PCK for NOS. Although PCK literature has provided several arguments on different kinds of PCK (general, domain or discipline-specific, and topic-specific PCK), none of the PCK for NOS studies aforementioned sought for the answer of "Which PCK category can fully explain the nature of PCK for NOS?" Based on literature, several arguments could be proposed. Utilizing the PCK taxonomies proposed by Veal and Makinster (1999) some might think that PCK for NOS is general PCK since it deals with knowledge and skills related to teaching science. Some others might see NOS as a topic in science and argue that PCK for NOS is topic specific (Hanuscin & Hian, 2009; Hanuscin et al., 2011; Lederman, 1998). NOS can be taught using content generic activities and topic-specific PCK have the potential to explain teachers' NOS teaching practice. On the other hand, NOS can be taught using content-embedded activities and one science teacher may teach the same aspects (e.g., nature of theories) when teaching different topics in a discipline (e.g., atom theories and kinetic molecular theory). At this situation topic-specific nature may not fully explain the way this teacher's NOS teaching attempt in two topics. Davis et al.'s (2008) arguments resolved the issue at this point; "…[w]hile PCK is typically conceptualized as topic-specific, teachers also need discipline-specific knowledge about how a discipline works" (p. 6). In their definition of PCK for disciplinary practices, Davis and Krajcik (2005) elaborated that teachers should have knowledge and skills that help students in understanding the discipline itself and when applied to science understanding the scientific endeavor it implies that teachers have PCK for NOS. The arguments on nature of PCK for NOS formed based on PCK literature should be supported by empirical research and moreover, there is a need for research on different types of PCK (e.g., general, discipline-specific, and topic specific) in order to deepen our understanding on science teacher knowledge (Abell, 2008). This study fills the gap in the literature in this regard.

2.6. Summary of the Literature Review

Development of pre-service chemistry teachers' STO, KoL, KoIS, and KoA and the nature of their PCK for NOS were investigated in this study. Therefore, literature was reviewed under the headings of NOS, teachers' understanding of NOS, factors affecting teachers' translation of their NOS understanding into class, PCK, and finally PCK for NOS.

NOS came into prominence in science education reform movements because of its contribution to an individual's SL (AAAS, 1993; Bauer, 1995; Layton et al., 1994; NRC, 1996; Shamos, 1995). After that point, stakeholders of science especially science educators tried to find the answers of what is NOS? What level of NOS understanding is necessary for students? and Which NOS aspects should be learned by students? Although the lack of clear-cut NOS definition accepted by all interested in NOS (Abd-El-Khalick & Lederman, 2000), there are some NOS aspects on which NOS related people reached a consensus by recognizing their essentiality for achieving scientifically literate citizenry. NOS refers to the epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its' development (Lederman, 1992). Various efforts were made in defining what constitutes NOS and which aspects provide a more coherent NOS understanding (Alters, 1997; AAAS, 1989; Irzık & Nola, 2011; Kimball, 1968; Matthews, 1998; MccOmas, 1998; McComas & Olson, 1998; Osborne et al., 2003; Rubba & Anderson 1978; Smith et al., 1997; Smith & Scharmann, 1999) for students to achieve SL. Although there have been some disagreements on a specific definition on NOS, there are some agreed upon important aspects of NOS which is relevant and accessible to K-12 (Abd-El-Khalick, Bell & Lederman, 1998; Lederman & Abd-El-Khalick, 1998; McComas & Olson, 1998; Osborne et al., 2003; Smith &Scharmann, 1999). The following aspects constituted our understanding of NOS and reflect the contemporary understanding on NOS as defined by literature.

- Scientific knowledge is tentative.
- Science is based on observations and experiment.
- Scientific knowledge is based on inferences as well as observations.
- Scientific theories and laws have different roles in science.

- Scientific knowledge is theory-laden and includes subjectivity.
- Creativity and imagination plays a major role in science.
- Social and cultural factors affect science.
- Science and technology is not the same thing.
- There is no universal and step by step scientific method.
- Serendipity plays a role in science.

Teachers' NOS understanding refers to their SMK in this study and is a pre-requisite for a well-developed PCK for NOS (van Driel et al., 1998).Therefore, after defining our understanding of NOS, the next step was to portray a clear picture of what teachers know about targeted NOS aspects. The efforts in examining what both pre- and in-service teachers know about NOS differed in the participants (e.g., elementary, elementary science, secondary science, pre-service, and in-service teachers) and the tools used for assessing teachers' NOS understanding (e.g., qualitative and quantitative). Whatever the tools they used or whoever the participating teachers, the results of these studies indicated that teachers do not have informed NOS understanding and moreover they have several misconceptions in NOS (Abd-El-Khalick & BouJaoude, 1997; Akerson et al., 2008; Aslan, 2009; Ayvaci & Er Nas, 2010 Brown et al., 2006; Chen, 2001; Doğan, 2005; Doğan et al., 2011; Erdoğan, 2004; Gürses et al.,, 2005; Haidar, 1999; Lederman, 1992; Liang et al. 2008; Liu & Lederman, 2007; Murcia & Schibeci, 1999; Şahin et al., 2006; Tairab, 2001; Thye & Kwen, 2003; Yalvaç et al., 2007) such as the purpose of science is to achieve abstract truth, scientific knowledge is absolute where the knowledge in other fields is not, experiments are crucial to reach scientific knowledge, with the proof theories become laws, theories can change while laws cannot, and the role of creativity and imagination is less than the scientific method itself.

Realizing the teachers' inadequate NOS understandings, science educators directed their attempts to improve teachers' conceptions of NOS as well as to improve students' NOS conceptions since they assumed that teachers with an adequate NOS understanding is able to translate his/her understanding into the classroom teaching. The efforts, aiming to improve teachers' NOS conceptions, could be categorized as implicit and explicit to NOS instruction (Abd- El-Khalick &

Lederman, 2000a). Advocates of implicit approach believed that students can learn NOS by engaging in authentic science activities without any connection to NOS while explicit approach advocated that enhancing learners' conceptions of NOS should be planned for and certain aspects of NOS should be made explicit in any attempt. After recognizing the effectiveness of explicit approach, science educators made some progress in enhancing teachers' NOS conceptions (Akerson et al., 2000; Abd-El-Khalick & Lederman, 2000b; Lin & Chen, 2002). However, subsequent researches indicated that teachers were not able to directly translate their informed NOS understandings into their teaching (e.g., Brickhouse, 1990; Brickhouse & Bodner, 1992; Hodson, 1993). To reveal the factors that resulted in the absence of clear-cut relationship, several studies conducted with pre-service and in-service teachers using mostly qualitative sources throughout their NOS teaching attempts. The associated factors with teachers' NOS teaching practices as evidenced by the literature are as follows;

- Teachers' beliefs and intentions (Abd-El-Khalick & Akerson, 2003; Bell et al., 2001; Herman, 2010; Lederman, 1999; Lederman et al., 2001; Sweeney, 2010)
- Classroom management (Abd-El- Khalick et al.,1998; Hodson, 1993; Lederman, 1999; Lederman et al., 2001; Ochanji, 2003)
- Pressure to cover science content covered in curriculum (Aslan, 2009; Brickhouse & Bodner, 1992; Hodson, 1993; Lederman et al., 2001; Ochanji, 2003; Koehler, 2006)
- Pressure from co-operating teachers and parents (Abd-El-Khalick et al., 1998; Aslan, 2009; Bell et al., 2000; Ochanji 2003, Koehler, 2006)
- Lack of SMK (Brickhouse & Bodner, 1992; Hodson, 1993; Lederman et al., 2001; Schwartz & Lederman, 2002; Wahbeh, 2009)
- Inadequate NOS understanding (Abd-El-Khalick et al., 1998; Akerson et al., 2009; Lederman, 1999; Lederman et al., 2001; Ochanji, 2003; Schwartz & Lederman, 2002)
- Time restrictions (Abd-El-Khalick et al., 1998; Bell et al., 2000; Brickhouse & Bodner, 1992; Hodson, 1993; Koehler, 2006)

- Absence of resources and experience for teaching NOS (Abd-El-Khalick et al., 1998; Akerson et al., 2010; Bell et al., 2000; Brickhouse & Bodner, 1992; Hodson, 1993; Lederman, 1999; Lederman et al., 2001; Wahbeh, 2009)
- Confusing NOS with scientific inquiry (Bell et al., 2000; Ochanji 2003; Koehler, 2006)
- Concern for students' abilities to learn NOS (Koehler, 2006; Sweeney, 2010)
- Undeveloped PCK for NOS (Abd-El-Khalick & Lederman, 2000a; Akerson & Volrich, 2006; Hanuscin et al., 2011; Lederman et al., 2001; Ochanji, 2003;Schwartz & Lederman, 2002; Wahbeh, 2009)
- Feeling responsibility for teaching NOS (Herman, 2010)
- Low self efficacy for teaching NOS (Akerson et al., 2009; Schwartz & Lederman, 2002)
- Presence of state wide tests (Aslan, 2009; Brickhouse & Bodner, 1992; Koehler, 2006)
- Absence of NOS in curriculum to be followed (Akerson et al., 2009; Akerson et al., 2010; Koehler, 2006; Lederman et al., 2001)

Among the factors listed above PCK for NOS is the one that science educators might help both pre-service and in-service teachers by designing courses and trainings that stimulate the development of PCK. Moreover, the need for designing professional development programs that help teachers to develop and revise existing materials and enable them to develop PCK for NOS considering all sub-dimensions namely STO, KoL, KoIS, KoA, and KoC has been well documented (Akerson & Abd-El-Khalick, 2003; Akerson &Volrich, 2006; Hanuscin & Hian, 2009; Hanuscin et al., 2011; Schwartz & Lederman, 2002). Also, the area of PCK for NOS requires increasing number of studies (Lederman et al., 2001), especially the ones using an explicit PCK framework (e.g., Magnusson et al., 1999). PCK is the knowledge that differentiates a scientist from a science teacher (NRC, 1996) and was first conceptualized by Shulman (1986). PCK, was defined as "….knowledge, which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching" (p. 8). After the work of Shulman (1986), more research was conducted on the components and nature of PCK (Davis et al., 2008; Davis & Krajcik, 2005; Gess-Newsome, 1999; Grossman, 1990; Shulman, 1987; Tamir, 1988;

Cochran et al., 1993; Magnusson et al., 1999; Veal & MaKinster, 1999). Following the recognition of PCK bin 1980s, science educators conceptualized PCK for NOS in 2000s as including

> … an adequate understanding of various aspects of NOS, knowledge of a wide range of related examples, activities, illustrations, explanations, demonstrations, and historical episodes. These components would enable the teacher 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 adapt those aspects to the diverse interests and abilities of learners (Abd-El-Khalick & Lederman, 2000, p. 692).

Although, literature provides various models for PCK, some researchers preferred to construct their own model for investigating teachers' NOS teaching attempts (Abd-El-Khalick, 2012; Jenny, 2011; Kim et al., 2005; Schwartz & Lederman, 2002) and very few utilized an already existing PCK model (Magnusson et al., 1999) by modifying it from the perspective of NOS teaching (Faikhamta, 2012; Hanuscin & Hian, 2009; Hanuscin et al., 2011). Magnusson et al.'s (1999) PCK model was originally proposed by science teaching and has an adaptable nature for different topics in science. These researchers using Magnusson et al.'s model provided evidence for the applicability of this model as a lens for research on NOS teaching (Faikhamta, 2012; Hanuscin & Hian, 2009; Hanuscin et al., 2011). In this study, Magnusson et al.'s (1999) PCK model by modifying it for NOS was used in this study when designing PCK for NOS instruction and analyzing the data. Although several studies considered what constitutes PCK for NOS (Faikhamta, 2012; Hanuscin & Hian, 2009; Hanuscin et al., 2011; Jenny, 2011; Kim et al., 2005; Schwartz & Lederman, 2002), they did not provide their arguments explicitly about the nature of PCK for NOS. Based on the literature on PCK some may advocate that PCK for NOS is a general PCK (Veal & MaKinster, 1999), some may claim that it is topic-specific (Hanuscin & Hian, 2009; Hanuscin et al., 2011; Lederman, 1998), and the others may provide their arguments in favor of discipline-specific nature of PCK for NOS (Davis & Krajcik, 2005; Davis et al., 2008). The nature of PCK for NOS is an area that needs further investigation and "Virtually no research has used the PCK perspective, which was so heavily researched during the 1990s, as a lens for research on the teaching of NOS." (Lederman, 2007, p. 870). Moreover, the interplay among various components of PCK for NOS should be investigated (Abell, 2008; Hanuscin et al., 2011). This research fills the gaps in the literature in these respects by examining how pre-service chemistry teachers' PCK for NOS components (STO, KoL, KoIS, and KoA) changed throughout a course in which enhancing teachers' NOS understanding and PCK for NOS were the main focus.

2.7. The Present Study

An important question that needs to be considered is "What is the place of our theoretical framework for PCK for NOS among the ones already exist in literature?" Literature provided several frameworks for PCK for NOS; some of them were developed by researchers (Abd-El-Khalick, 2012; Abd-El-Khalick & Lederman, 2000; Jenny, 2011; Kim et al., 2005; Schwartz & Lederman, 2002), another was modified using an already existing PCK model, Magnusson et al., 1999, (Faikhamta, 2012; Hanuscin & Hian, 2009; Hanuscin et al., 2011), and one was defined as degree of integrating NOS in lesson plans (Pongsanon et al., 2011). Although they may seem as different frameworks, when examined more closely these frameworks shared some shared elements (see table 4). Moreover, these elements constitute the components of PCK proposed by Magnusson et al. (1999).

Table 4. PCK for NOS frameworks in literature with their components

Components	PCK for NOS Models					
	Abd-El-Khalick & Lederman (2000)	Schwartz & Lederman (2002)	Kim et al., 2005	Jenny (2011)	Faikhamta, 2012; Hanuscin & Hian, 2009; Hanuscin et al., 2011	Abd-El-Khalick, 2012
NOS	X	X	X	X	X	X
SMK		X	X	X	X	X
PK		X	X	X	X	
STO		X	X	X	X	
KoIS	X	X	X	X	X	X
KoL	X			X	X	X
KoC					X	
KoA				X	X	X
HOS		X	X	X	X	X

In this study, Magnusson et al.'s (1999) model guided me in designing the PCK for NOS instruction and analyzing the data (see Figure 8). There were several reasons for this; firstly, Magnusson et al.'s (1999) model has an additional feature that goes beyond the PCK components. Magnusson et al. did not see their model just as a collection of the proposed components namely STO, KoL, KoIS, KoC, and KoA. Moreover, they emphasized that teachers should have all PCK components and a teacher's PCK highly depends on to what degree the components are integrated and coherent, which was also recognized by others (Friedrichsen et al., 2009; Park & Oliver, 2008a). This nature was not considered by other PCK models in literature although they include some components of Magnusson et al.'s (1999) model as indicated above (table 4). In this study, I considered not only the components but also the integration and coherence among the components in analyzing the data and deciding the quality of participants' PCK for NOS. Secondly, researchers using Magnusson et al.'s model provided evidence for the applicability of this model as a lens for research on NOS teaching (Hanuscin & Hian, 2009; Hanuscin et al., 2011). Thirdly, I tried to fill the gap ,in literature by responding the need for designing professional development programs enable teachers to develop PCK for NOS considering all sub-dimensions namely STO, KoL, KoIS, KoA, and KOC has been well documented (Akerson & Abd-El-Khalick, 2003; Akerson &Volrich, 2006; Hanuscin & Hian, 2009; Hanuscin et al., 2011; Schwartz & Lederman, 2002).

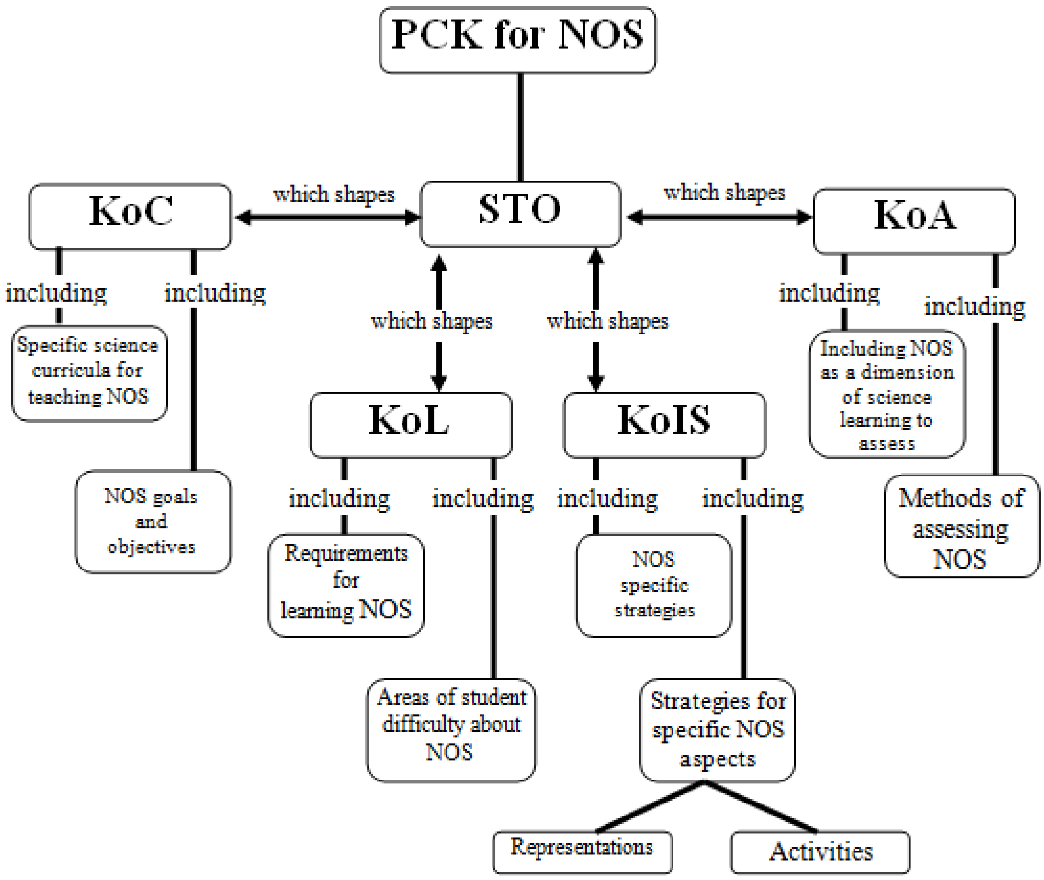

Figure 8. PCK for NOS model, modified using Magnusson et al.'s (1999) PCK model, guiding this study

All the PCK components except KoC were addressed in this study since KoC was not relevant to Turkey context in terms of NOS. First of all, there are no specific

NOS objectives in secondary chemistry curriculum. Also, lack of specific curriculums and materials for teaching NOS in Turkey leaded us to exclude KoC and to focus on four which are STO, KoL, KoIS, and KoA from the perspective of NOS teaching. How these components addressed throughout our PCK for NOS instruction and analyzed will be explained in detailed in Chapter 3.

CHAPTER III

METHODOLOGY

This study mainly focused on how pre-service chemistry teachers' PCK for NOS including STO, KoL, KoIS, and KoA developed throughout PCK for NOS instruction. This chapter will provide information about the methods and procedures that were used in the study under the several subtopics. First of all, research design and the rationale for the research design will be discussed. Then, participants, procedure, context, data collection methods, and data analysis procedures will be designated. Finally, validity and reliability issues, ethical considerations, assumptions and limitations will be presented.

3.1. Research Questions

The main research question of the study was:

How is pre-service chemistry teachers' PCK for NOS including STO, KoL, KoIS, and KoA developed throughout PCK for NOS instruction?

The sub-problems of this study were:

1. What kinds of views do the preservice chemistry teachers have on the nature of science concepts before explicit-reflective NOS instruction?
2. What kinds of views do the preservice chemistry teachers have on the nature of science concepts after explicit-reflective NOS instruction?
3. Which components of PCK for NOS do pre-service chemistry teachers develop throughout PCK for NOS instruction?
4. How and to what degree do pre-service chemistry teachers integrate the components of their PCK for NOS?
5. How and to what degree do pre-service chemistry teachers translate PCK components into their lesson plans?

6. How are pre-service chemistry teachers' NOS understanding and their PCK for NOS related?
7. Which PCK model (general PCK, discipline-specific PCK, or topic specific PCK) best explains the nature of PCK for NOS?

3.2. Research Design and Rationale

This research is qualitative-interpretive in nature. Marshall and Rossman (2006, p. 53) emphasized the strengths of qualitative methodology for several types of research;

- Research that elicits tacit knowledge and subjective understandings and interpretations,
- Research on little-known phenomena or innovative systems
- Research that cannot be done experimentally for practical or ethical reasons, and
- Research that delves into complexities and processes.

The main concern of this study was to understand how pre-service chemistry teachers developed and translated various PCK components (STO, KoL, KoIS, and KoA) throughout the PCK for NOS instruction. Tacit nature of PCK has been well documented in the related PCK literature (Loughran, Mulhall, & Berry, 2004; 2008; Loughran & Berry, 2010). Therefore, qualitative methodology helped to make tacit nature of PCK for NOS explicit by the use of multiple data sources (e.g., lesson plans, reflection papers, and field notes). Also, in this study, since an innovative system (PCK for NOS instruction) and little known phenomenon (PCK for NOS) were the focuses of the study, qualitative methodology provided in-depth information about the phenomenon being investigated. Another reason why qualitative methodology was utilized in this study is that this study had one group of participants who were trained in PCK for NOS instruction and there was no control group. That is, this research could not be done experimentally for practical reasons. Finally, delving into the complexities and process was achieved by qualitative methodology using multiple data sources throughout the PCK for NOS instruction (process) and understanding not only each PCK components but also the integration among them (complexities).

As well as the strengths of qualitative methodology which are utilizable for this research to deeply/better understand the nature of pre-service teachers' PCK, qualitative research has several key characteristics related to methodology which are pertinent to this study (Creswell, 2007):

- Natural setting: The data were collected in the field where participants experience the issue or problem under study. PCK for NOS instruction was a part of a two-semester elective course "Research in Chemistry Education" and the participants had been learning about NOS in this course before the PCK for NOS instruction begun. During the natural schedule of this two-semester course, several weeks were devoted to PCK for NOS instruction which was a natural setting for the participants.
- Researcher as a key instrument: In this study, the researcher collected data herself by examining documents, observing behavior, and interviewing participants.
- Multiple sources of data: The researcher relied on multiple forms of data such as responses given to open ended instruments, interviews, observations and documents such as lesson plans and reflection papers. Then, the researcher analyzed all the data by organizing them into themes or categories.
- Participants' meanings: The researcher tried to focus on the meaning that participants had about NOS and PCK for NOS by using their self-generated data and interviews.
- Theoretical lens: In this research, the PCK lens was used to understand how pre-service chemistry teachers translated their NOS understandings into their practices.
- Holistic account: The researcher tried to develop a complex picture of development and nature of PCK for NOS by identifying not only each PCK component but also integration among the components within the context of PCK for NOS instruction.

In short, extensive description of the nature and development of pre-service chemistry teachers' PCK for NOS during PCK for NOS instruction was the main concern of this study, which is appropriate to qualitative research approach (Creswell, 2007). Moreover, as Bogdan and Biklen (2007) referred, the data collected in this qualitative research were rich in description and not handled by statistical procedures.

Case study, one of the qualitative research traditions, guided this study in designing, collecting, and analyzing the data. Case study is the study of an issue investigated through one or more cases within a bounded system (i.e., setting, a context) (Creswell, 2007). Qualitative case studies can provide an in depth portrayal and analysis of a particular practice, process, or event (McMillan & Schumacher 2001). Case can be defined as a phenomenon of some sort occurring in a bounded context (Miles & Huberman, 1994) and may be an individual, a role, small group, organization, community, nation, decision, policy, process, incident, and event of some sort (Creswell, 2007). The selection of case is not related to its representativeness rather the uniqueness and being illustrative of an issue affects whether the case is selected or not (McMillan & Schumacher, 2001). In this study, the pre-service chemistry teachers receiving PCK for NOS instruction formed the case since they were unique in that there was no other group receiving any type of PCK for NOS instruction.

Case study does not control the behavioral events instead focuses on contemporary ones and by this way tries to answer how and why questions (Yin, 2003). This study focused on a contemporary event (the development and nature of PCK for NOS during PCK for NOS instruction, which was a part of two-semester long course on NOS) and examined how pre-service chemistry teachers developed PCK for NOS. The aim of the case study is to expand and generalize theories not the statistical generalization (Yin, 2003). The aim of this case study was to expand the theory of PCK for NOS by utilizing the Magnusson et al.'s (1999) PCK model for science teaching, which was used by several others (Faikhamta, 2012; Hanuscin & Hian, 2009; Hanuscin et al., 2011). Yin (2003) defined the case study as "… an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (p. 13). Moreover, he emphasized that one would use the case study since s/he wants to consider contextual conditions as these conditions might be relevant to the phenomenon being investigated. In this case study, the PCK for NOS instruction might be pertinent to the development of participants' PCK for NOS. There are four characteristics of case studies which were present in this study; bounded system (PCK for NOS instruction), case of something (pre-service chemistry teachers receiving the PCK for NOS instruction), holistic (studying each participants PCK for NOS and comparing them in their totality), multiple sources of data (open ended instruments, interviews, observations and documents such as lesson plans and reflection papers) (Punch, 2005).

There are several types of case studies depending on the size of the bounded case and the intent of the case analysis (Creswell, 2007; Yin, 2003). Considering the size of the bounded case, case study research can be a single- or multiple-case study. Determining whether a case study is single or multiple is highly depends on the research questions being investigated. Multiple-case study is conducted for the purpose of either predicting similar results (a literal replication) or predicting contrasting results (a theoretical replication) through the use of different cases which are different from each other in some respect (e.g., experienced teachers and beginning teachers or females and males).On the other hand, the circumstances for conducting single-case study can be listed as; critical case (case meeting all of the conditions for testing a well-formulated theory), extreme or unique case (the case/s having particular characteristics which are seldom encountered), representative or typical case, revelatory case (the case which is previously inaccessible to scientific investigation), and longitudinal case (studying the same single case at different points in time) (Yin, 2003). The present study constituted a single-case study (one group of pre-service chemistry teachers receiving PCK for NOS instruction) by selecting the representative or typical case, one of the single-case studies. The participants of this study were not different from other groups of pre-service chemistry teachers in other chemistry teacher education programs at different universities. The group was in their last year of a five-year chemistry teacher education program, which will be explained in detail in the participants part, and represented the typical senior year chemistry teacher undergraduates. Case studies are also distinguished by considering the purpose (Yin, 2003); exploratory, descriptive, and explanatory case studies. Exploratory case studies focus on exploring phenomenon in the data while explanatory ones explain the phenomena and might yield to theory development. Descriptive case studies aim to describe the phenomenon in the data by using pre-established theories. This study was a descriptive single-case study since the focus was to describe the way that pre-service chemistry teachers' develop PCK for NOS and translated it into their lesson plans by using an already existing PCK model (Magnusson et al., 1999), which was also used by others (Faikhamta, 2012; Hanuscin & Hian, 2009; Hanuscin et al., 2011).

3.3. Participants

Participants included 30 pre-service chemistry teachers (8 males and 22 females). They were enrolled in an elective course, "Research in Chemistry Education" course, where NOS was taught during 2009/2010 spring semester. All the participants started the undergraduate program in 2005 and their ages ranged between 22 and 24 with an average of 23. All were in their senior year and in a position to graduate at the end of 2009/2010 spring semester. Each had similar background in terms of coursework; including chemistry courses, pedagogical courses, and subject-specific pedagogical courses (see Appendix A for the whole chemistry teacher education program including courses, course credits, and course hours). The participants were not familiar with the content of Research in Chemistry Education course since they had not received explicit NOS instruction in their previous courses. However, some of the participants had taken one-semester long History of Chemistry course before taking this course. Pre-service chemistry teachers were asked about what they learned in that course. They stated that they just learned how chemical ideas developed throughout the history and there was no explicit-reflective discussions guided by the instructor of that course with the purpose of teaching NOS.

3.4. Context: Research in Chemistry Education Course

A chemistry teacher education program at a public university in Ankara constituted the context for this study. This five-year program certifies undergraduates as chemistry teachers for grades 9-12. During their five year program (see Appendix A), chemistry education majors take chemistry courses (e.g., general chemistry, analytical chemistry, organic chemistry, industrial chemistry), general pedagogical courses (e.g., introduction to education, instructional planning and evaluation), subject-specific pedagogical courses (e.g., methods of science teaching, laboratory experiments in science education), and elective chemistry and chemistry education courses (e.g., atomic spectroscopy, history of chemistry, research in chemistry education). A two-semester elective Research in Chemistry Education course of which content is parallel with recent reform movements in science education was the focus of this study. This elective course was framed with the purpose of teaching NOS and how to teach NOS to pre-service chemistry teachers during 2009/2010 fall and spring semesters. At the same time, throughout these two semesters, the course was formed the context for the second year of a three-year project, funded by The Scientific and Technological Research Council of Turkey (TUBITAK) aiming to help both pre- and in-service teachers develop their understanding of NOS and ability to teach NOS (Project Number: 108K086). Research in Chemistry Education course included two main phases: In the first phase, pre-service chemistry teachers learned about NOS in an explicit-reflective manner and in the second phase, they received PCK for NOS instruction stimulating the development of their PCK for NOS. Therefore, the context will be introduced under two sub-headings; NOS instruction and PCK for NOS instruction.

3.4.1. NOS Instruction

Since NOS understanding, which refer to pre-service chemistry teachers' SMK in this study and is a pre-requisite for a well-developed PCK for NOS (van Driel et al., 1998), participants first learned about NOS. Numerous studies on how to teach NOS have provided evidence for the effectiveness of explicit-reflective approach over an implicit one (Akerson et al., 2000; Abd-El-Khalick & Lederman, 2000a; Lin & Chen, 2002; Matkins, Bell, Irving, & McNall, 2002). Therefore, in this study, all the activities were designed in a way that participants had a chance to reflect on their experiences, gained through engaging in the activity, from the perspective of NOS through the use of cognitive tools. Pre-service chemistry teachers engaged in both content generic and subject-specific activities, which is in line with NOS teaching literature, to address NOS (see Table 5 for all activities). All activities will be briefly explained below and activity sheets for each are provided in Appendix B. First Step in NOS Teaching: New Society Activity, Object Coming from Space- The Role and Importance of Models in Science, and Competing Theories- Lamarck and Darwin were modified from the activities available in NOS literature while Mysterious Stones- Lithology, Phases of the Moon-Lunar and Solar Eclipses, A Case from HoS: Phlogiston and Foundation of Modern Chemistry, Discovery of DNA, Thought Experiments, Superconductivity, and Science and Technology: In the Pursuit of Seharap-Designs are Competing were developed by researchers studying in TUBITAK project.

Table 5. How did each explicit-reflective NOS activity address various NOS aspects focused in this study?

Explicit-reflective NOS activities	NOS aspects: Scientific knowledge is tentative	Science is based on observations and experiments	Scientific knowledge is based on inferences as well as observations	Scientific theories and laws have different roles in science	Scientific knowledge is theory-laden and includes subjectivity	Social and cultural factors affect science	Creativity and imagination plays a major role in science	Science and technology is not the same thing	There is no universal and step by step scientific method	Serendipity plays a role in science
1. First Step in NOS Teaching: New Society Activity*	√	√	√		√	√	√		√	√
2. Mysterious Stones-Lithology**	√	√			√		√			
3. Phases of the Moon-Lunar and Solar Eclipses**		√			√					
4. Competing Theories-Lamarck and Darwin*		√	√		√				√	
5. Object Coming from Space-The Role and Importance of Models in Science*	√	√	√				√			
6. A Case from HoS: Phlogiston and Foundation of Modern Chemistry**	√	√	√		√	√				√
7. Discovery of DNA**	√	√			√	√				
8. Thought Experiments**		√					√		√	
9. Superconductivity**	√	√		√						
10. Science and Technology: In the Pursuit of Seharap-Designs are Competing**							√	√		

* Modified from the activities available in literature

** Developed by researchers studying in TUBITAK project

First Step in NOS Teaching - New Society Activity: Four participants, who are the scientists, were asked to wait at the outside of the classroom. Then, the participants in the classroom were told that they were the citizens of a new society and lived according to several rules. The participants in classroom were informed about the rules which were; (a) The society members' only vocabulary is either "yes" or "no." (b) If the scientist is smiling when he/she asks them a question, then the answer is always "yes," and if the scientist is not smiling when asking the question, the answer is always "no," regardless of the question and the accuracy of the response. (c) Depending on which outstanding characteristic we used among our scientist group (e.g., either gender, hair color, or glasses) the society members can only speak, that is say yes or no, to the scientists who have the same characteristic that you have chosen, or in the case of gender, the opposite characteristic. The scientists waiting outside of the classroom were told that they discovered a new society and their task was to find out as much as they can. Right after the scientists had entered the classroom, they started to find out the characteristics of the new society. When all the rules are discovered, the instructor/s conducted an explicit-reflective class discussion on "what is science?" and "how it works?" (Cavallo, 2008; Yeşiloğlu, Demirdöğen, & Köseoğlu, 2010).

Mysterious Stones - Lithology: In this activity, the groups of participants classified the 13 stone samples belonging to various geological classes. The groups were asked to do their classification based on a reasonable rationale and scientifically meaningful characteristic. The groups who had finished the classification based on their first observations were given the physical characteristics and chemical formulas of the stones and were asked to reclassifies the stones again. After completion of the two round classifications, the groups presented their classifications together with their justifications. A whole class explicit-reflective class discussion was conducted by the instructor/s on observation and inference, creativity and imagination, and subjectivity in science and tentativeness of scientific knowledge.

Phases of the Moon-Lunar and Solar Eclipses: At the beginning, the groups of participants were asked to share their ideas on phases of the Moon, Lunar and Solar eclipses. Then, the groups were distributed ping pong ball, torch, and stick. They were asked to construct models using these materials and investigate how the phases of the Moon, Solar and Lunar eclipses occur by using the models. When the groups completed their models and provided their explanations, they shared all these to the other groups. After the presentations, the instructor/s conducted an explicit-reflective class discussion on roles on models in science, if scientific models are copies of reality, and whether experiments are the principal routes to scientific knowledge.

Competing Theories - Lamarck and Darwin: In this activity, the participants were asked to form groups of A and B. Group A and Group B included 4-5 participants and there were more than one Group A and Group B. Group A was introduced the evolution theory of Lamarck and Group B was introduced the evolution theory of Darwin. After the introduction, the groups were asked to form hypothesis which schematize how human and monkey species emerged. DNA sequences of these species were given to the groups to test their hypothesis. Group A and B presented their hypothesis and how they supported or refuted their theories presenting their data and evidences after completion of the group work on hypothesis formulation and testing. During the presentations, the groups realized how they had been influenced by the theories they were given at the beginning. At the end of the activity, the instructor/s conducted a whole class explicit-reflective discussion on observation, inference, and subjectivity in science and scientific method (National Academy of Sciences, 1998).

Object Coming from Space - The Role and Importance of Models in Science: The participants are told that an object came from space and their task is to propose a model which explains the behavior of that object. The object was a closed cylinder which has four ropes coming out of four different holes on the cylinder. This object was shown to the participants and they were asked to observe what happens when each rope was pulled out. The participants worked in groups of four or five in order to propose and construct a model regarding to how the system inside the cylinder works. After the groups had completed their works, each group presented their models and explained how they construct their models based on the observations, hypothesis, and tests. There was more than one possible model which successfully explains the behavior of the ropes coming out of the cylinder. Hence, at the end of the activity, the instructor/s conducted an explicit-reflective whole class discussion on the difference between observation and inference, hypothesizing and testing, and the role of models in science (Lederman & Abd-El-Khalick, 1998).

A Case from HOS - Phlogiston and Foundation of Modern Chemistry: The phlogiston is the scientific theory about how the burning occurs and was accepted by the scientific community until the oxygen theory was formulated throughout the 18th century. According to this theory burning matters include phlogiston and they emit phlogiston when they burn. In this activity, phlogiston and oxygen theory were introduced to the participants. The participants were asked to test these two theories using the scientific reasoning of “If...and…then…and/but…therefore…” and scientific knowledge that exist in 18th century about burning. After that, the existence of data which are incompatible with phlogiston theory and the acceptance of oxygen theory were reviewed with the participants. At the end of the activity, the/instructor/s conducted a whole class explicit reflective discussion on observation and inference, social-cultural factors, and subjectivity in science.

Discovery of DNA: There were several activities in Discovery of DNA activity; formation of DNA model during the process of discovery of DNA, synthesizing DNA from banana, sharing an article about life of Rosalind Franklin, and solving a criminal case using scientific method. After all of these activities, the instructor/s conducted a whole class discussion on empirical based, tentative, and socially and culturally embedded nature of science. Also, there is no universally accepted scientific method followed by every scientists were discussed.

Thought Experiments: Various thought experiments in science (e.g., Galileo’s free fall experiment and Schrödinger’s Cat) were introduced to the participants at the beginning of this activity. Then, the participants discussed the experiment of Schrödinger’s Cat by using the model of that experiment. At the end of the activity, the instructor/s conducted an explicit-reflective whole class discussion on two common myths; the experiments are the principal routes to scientific knowledge a general and universal scientific method exists.

Superconductivity: At the beginning of the activity, the participants watched a video on superconductivity and were asked to explain what they observed. After that, theories proposed to explain superconductivity were introduced by conducting an explicit-reflective discussion on how scientific knowledge changed based on new data. Additionally, the difference between theory and law were discussed based on superconductivity theory in the same way.

Science and Technology: In the Pursuit of Seharap - Designs are Competing: At the beginning, the participants were presented a problem which they can face with in their daily life. The problem was “Design a vehicle which makes the transportation easier and safer for the farmers who have to climb high mountains to collect Seharap”. The participants were asked to work in groups of four or five to design a technological product or method which solve that problem. After completion of design phase, the groups built the models of their designs, tested their models, and revised it if needed. Hence, the participants experienced the technological design process. At the end of the activity, the instructor/s conducted an explicit-reflective whole class discussion on the difference between science and technology and relationship between them.

3.4.2. PCK for NOS Instruction

After ensuring that pre-service chemistry teachers had learned about NOS, PCK for NOS instruction started. The main idea behind this instruction was to stimulate the development of the participants’ PCK for NOS. As explained in the literature part, Magnusson et al.’s (1999) PCK for science teaching model guided the study in designing the PCK for NOS instruction. All the PCK components except KoC were addressed throughout the instruction since KoC was not relevant to Turkey context in terms of NOS. First of all, there are no specific NOS objectives in secondary chemistry curriculum. Also, lack of specific curriculums and materials for teaching NOS in Turkey leaded us to exclude KoC. All activities constituting PCK for NOS instruction activities were planned by the researcher and reviewed by faculty with expertise in teaching and learning about NOS. This instruction spanned four weeks (corresponding to 12 in-class hours) and each week was dedicated to different component (STO, KoL, KoA, KoIS). General flow of each session was as follows:

- Participants answer a series of open-ended questions eliciting their ideas about the targeted component of PCK for NOS.

- Participants engaged in argumentative discussions within small groups, and presented their ideas to the class.
- The instructor facilitated the discussions and wrapped up the session with a presentation related to the session's focus.
- Participants wrote reflection paper on their learning on teaching NOS at the end.

How each PCK for NOS component addressed throughout our PCK for NOS instruction will be explained below. In addition, see Appendix C for activity sheets used throughout each week.

3.4.2.1. Science Teaching Orientation

The purpose of this class was to reveal participants' orientations to teach chemistry and then help them to understand the value of NOS teaching for achieving scientific literacy through reflection. Before the class began, participants individually answered the open-ended questions of "What is the goal of science and especially chemistry education?" and "What kind of instruction do you design to achieve the goals you mentioned in previous questions?" After completion of the questions, pre-service chemistry teachers watched a video of a mother who has to decide whether or not to get her baby vaccinated for swine flu (socio-scientific decision making). Then the participants were presented with two different science teachers' arguments (one claims that it is enough to know biology and science concepts and the other advocates that further knowledge is needed to decide on socio-scientific issues) on what that mother in the video needs to know for an informed decision making about getting vaccinated her baby. The participants were asked to select one of the arguments by providing their evidences and warrants. During this process pre-service chemistry teachers worked in group of 5 or 6. After each group discussed on whom to support, one of the participants from each group presented their ideas to the class. During these presentations, the instructor facilitated the discussions and guided the participants in understanding the importance of learning NOS for an informed decision making on socio-scientific issues. After the discussion, the instructor closed the session with a presentation on scientific literacy and the importance of NOS for achieving it. The participants wrote a reflection paper on “what did you learn from this class about chemistry teaching?” after that presentation.

3.4.2.2. Knowledge of Learner

Arguing about various NOS conceptions enabled pre-service chemistry teachers to realize difficulties and misconceptions about NOS that their future students might have. For this class, concept cartoons were prepared using the common myths of NOS (McComas, 1998, see Appendix C). Although McComas (1998) listed 15 myths about NOS there were 11 concept cartoons since in some cases one concept cartoon included more than one myth related to each other. After preparation of the concept cartoon, each was enclosed to a separate envelope having different color. Before this class had begun the participants individually answered the open-ended questions of “What might your students already know about NOS? Why do you think that they might know that?” and “Where do you think they might have learned these?” The purpose of these questions was to understand whether pre-service chemistry teachers were aware of the possible misconceptions that their future students might have. After the questions were answered, the participants were told that they received some letters from science teachers who encountered problems when teaching NOS and needed their help. The main task of the participants was to select one of the ideas of which they believe that it was true by providing their evidences and warrants. Also, the participants were expected to explain how they could convince a student believing a myth about NOS. During this process pre-service chemistry teachers worked in group of 5 or 6 and answered the questions of Which students’ idea is accepted, which one is misconception? What is the source of misconceptions? And how can a teacher challenge a student to confront his/her misconceptions? After each group discussed on whom to support, one of the participants from each group presented their ideas to the class. During these presentations, the instructor facilitated the discussions and guided the participants in understanding the myths, sources of them, and as a teacher what they should do in their teaching. After the discussion, the instructor closed the session with a presentation on common myths in literature and sources of them (McComas, 1998).

The participants wrote a reflection paper on "what did you learn from this class about chemistry teaching?" after that presentation.

3.4.2.3. Knowledge of Instructional Strategies

In this class, pre-service chemistry teachers analyzed mainly two lesson plans prepared on the topic of colligative properties (One of the lesson plan used implicit approach for teaching NOS and the other used explicit-reflective one for teaching the same NOS aspect) and argued on two science educators' views on the effectiveness of two NOS teaching approaches (implicit versus explicit-reflective) and thus enhanced their KoIS for teaching NOS. Before this class began, the participants individually answered the open-ended question of "What kind of instructional strategies do you use for teaching NOS and chemistry concepts at the same course hour?" After completion of the questions, pre-service chemistry teachers were told that a chemistry teacher needed their help in designing a chemistry lesson in a way to teach both chemistry and NOS concepts. For this task, the participants formed groups of 5 or 6 and the two lesson plans were distributed to each group. The groups were asked to analyze the lesson plans by comparing and contrasting them considering the several issues such as objectives in each plan, teaching approach used in each plan, and the appropriateness of teaching approach in each plan for the objectives. When the analysis of lesson plans completed, one participant from each group presented their ideas on two lesson plans (objectives, teaching approach, and appropriateness). Then, ideas of two science educators on lesson planning (one supports the use of the lesson plan utilizing the implicit approach and the other one supports the use of other lesson plan utilizing the explicit-reflective approach) were presented to the groups in activity sheet and the groups were asked to select one of the ideas by providing their evidences and warrants. Right after groups had completed their discussion, each group presented their ideas on whom to support. During these presentations, the instructor facilitated the discussions and guided the participants in understanding the importance of using explicit-reflective approach in effective NOS teaching. After the discussion, the instructor closed the session with a presentation on various approaches to teaching NOS. The participants wrote a reflection paper on “What did you learn from this class about chemistry teaching?” after that presentation.

3.4.2.4. Knowledge of Assessment

Participants assisted a chemistry teacher with aligning his/her assessment task with the lesson objectives including chemistry and NOS and this task helped pre-service chemistry teachers to consider NOS as a dimension of science learning and the methods by NOS can be assessed. At the beginning of the class, the participants were told that they would assist a chemistry teachers having difficulty in aligning his/her assessment with the lesson objectives. The participants were not explicitly told that the chemistry teacher had difficulty in assessing NOS since one of the purposes of the class was to understand whether the participants included NOS in their knowledge of what to assess. After this instruction, the participants formed groups of 5 or 6 and then objectives of the teacher were distributed to the groups. The groups were expected to design specific assessment task for the objectives instead of suggesting general assessment strategies. After completion of the group works, each group presented which objectives they assessed and how they did it. During these presentations, the instructor facilitated the discussions and guided the participants in understanding the importance of assessing NOS if one teacher integrated NOS in his/her lesson. After the discussion, the instructor presented an example of assessment that could be used to assess the objectives of the teacher. Then the session was closed with a presentation on various approaches to assessing. The participants wrote a reflection paper on “What did you learn from this class about chemistry teaching?” after that presentation.

3.5. Data Collection Sources

Qualitative data sources formed the data collection tools in this study and the tools integrated within the context is presented in Figure 9. It provides a big picture of how the data collection occurred within various course activities. Data sources which provide for the case study may be documents, archival records, interviews, direct observation, participant observation, and physical artifacts (Yin, 2003). Documents including Views on Nature of Science Questionnaire Form C (VNOS-C, Lederman et al., 2002), open ended instruments, lesson plans, and reflection papers, interviews, and participant observation formed the sources of evidence in this study to gain an in-depth information about pre-service chemistry teachers' nature and development of PCK for NOS. VNOS-C in conjunction with follow up interviews was used to assess participants' views on NOS. Interviews, reflection papers, responses given to open ended instruments, observational records including videos, and lesson plans were used to understand the nature and development of PCK for NOS. Each data source will be elaborated in detail. As known, each source has strengths and limitations peculiar to oneself. Thus, by using different kind of data collection sources the researcher will have a chance to compensate the limitations in one method by the strengths of a complementary one. Also, designing a study in which multiple cases, multiple informants or more than one-data gathering method is used can greatly strengthen the study's usefulness for other settings (Marshall & Rossman, 2006).

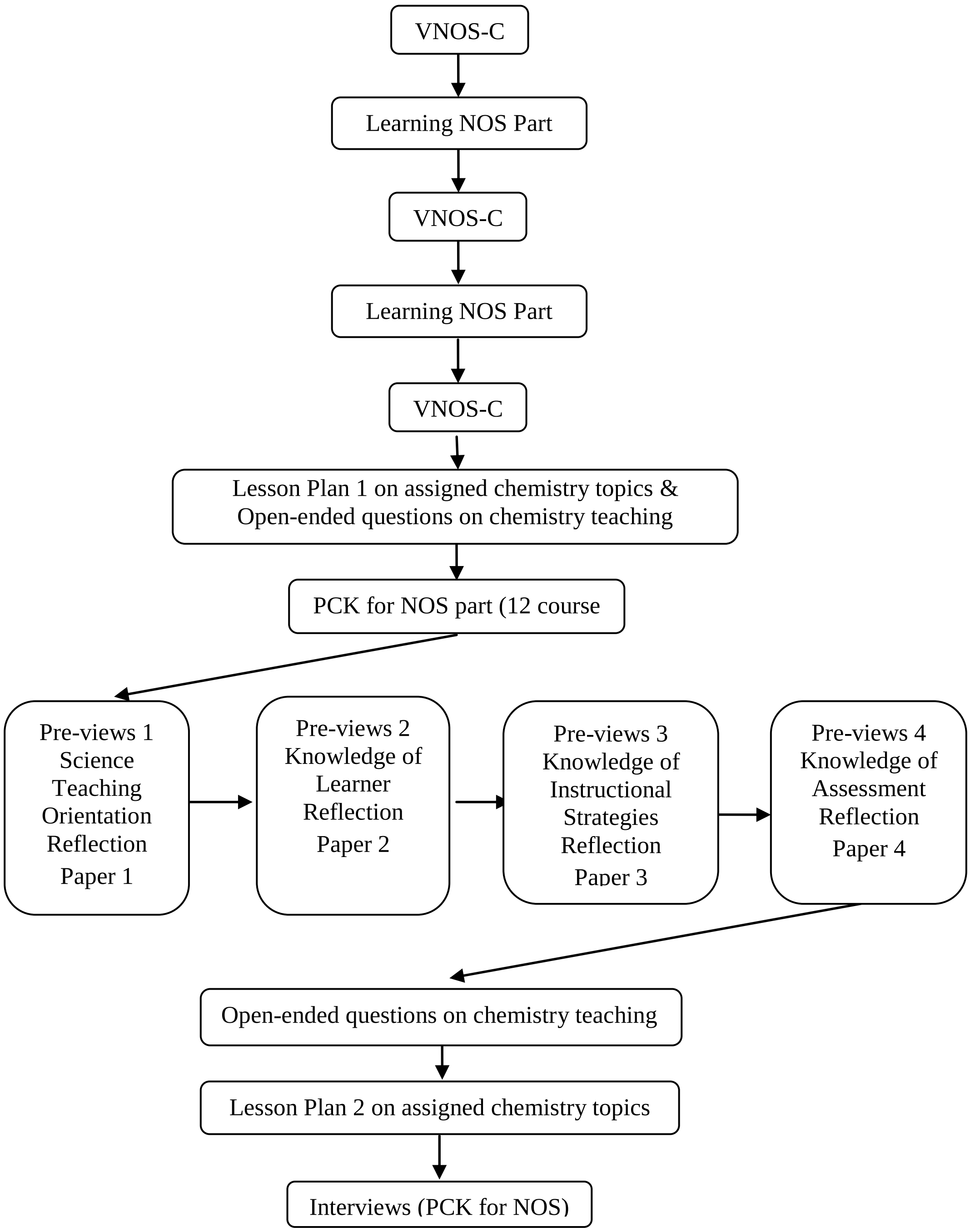

Figure 9. How data collection was occurred within the various course activities

3.5.1. Views on Nature of Science Questionnaire Form C

Assessment of NOS understanding has been a concern for science educators for over 40 years (Lederman, 2007). These efforts yielded various qualitative (e.g., VNOS-C by Lederman et al., 2002 and critical incidents by Nott & Wellington, 1998) and quantitative (e.g., VOSTS by Aikenhead & Ryan, 1992; Nature of Scientific Knowledge Scale by Rubba & Anderson, 1978) instruments that can be used NOS in different grades. In spite of their advantages in administration and analysis process, quantitative instruments are criticized because they are not enough to gain in-depth information about participants' NOS views and may yield inconsistent data with the data obtained from interviews (Lederman & O'Malley, 1990). Lederman et al. concluded that VNOS-C aimed to elucidate learners' NOS views and generate profiles of the meanings they ascribe to various NOS aspects for the purpose of informing the teaching and learning of NOS rather than for labeling learners' views as adequate or inadequate or sum their NOS understandings into numerical scores. Also, conducting follow-up interviews right after administration of VNOS-C was strongly suggested for increasing the validity (Lederman, 2007). Therefore, VNOS-C, including open-ended questions about targeted NOS aspects in this study, in conjunction with follow-up interviews was used to understand the meanings that participants ascribed to NOS aspects was used in this study (Lederman et al., 2002, see Appendix D). The questions and related NOS aspect in VNOS-C are as follows;

- Question 1: General idea about what science is and empirical nature of science
- Question 2: Nature and purpose of experiments
- Question 3: Role of experiments and experimental evidence in development of scientific knowledge
- Question 4: Tentative nature of science and the reason for tentativeness
- Question 5: Distinction between theory and law
- Question 6: Distinction between observation and inference and nature of models

- Question 7: Imaginative and creative and empirical nature of science
- Question 8: Role of scientific evidence in scientific knowledge and subjective nature of science
- Question 9: Imaginative and creative, and social cultural embeddedness nature of science and role of scientific evidence
- Question 10: Imaginative and creative nature of science

VNOS-C in conjunction with follow-up interviews was used as main data collection source in identifying how pre-service chemistry teachers' NOS views changed. Although there were 10 activities in NOS instruction, some activities lasted more than three course hours corresponds to at least two weeks. Therefore, the implementation of 10 activities spanned one and half semester. VNOS-C was administered three times; before NOS instruction (at the beginning of first semester), during NOS instruction (at the end of first semester), and finally after NOS instruction (in the mid of second semester). Some of the participants' NOS views as measured by VNOS-C during NOS instruction were missing. Therefore, in this study the change in pre-service chemistry teachers' NOS understandinhg will be elaborated in terns of how they were used to understand NOS before NOS instruction and what kind of NOS views they had after NOS instruction.

3.5.2. Open-ended Questions

Two types of open-ended questions were used to investigate how the participants' PCK for NOS developed over the Research in Science Education Course. The first question was used to understand whether learning NOS part influenced participants' views on chemistry teaching (e.g., if participants saw the value of NOS for their future teaching, if yes, how they decided to teach NOS). Also, this question with the addition of new ones was administered after PCK for NOS instruction to make a comparison between pre-service teachers' views on chemistry teaching before and after PCK for NOS instruction. The questions used after learning NOS part were as follows:

- As a teacher candidate, in your view, what is the goal of science education and specifically chemistry education?

- As a teacher, in your view, what kinds of knowledge, skills etc. a student, learning science/chemistry based on the science/chemistry curriculum, should have?
- Why is it important for your students to have the aforementioned knowledge/skills/objectives, listed in the previous two items? In other words, what is the difference between the students having those knowledge/skills/objectives and the students who do not have?
- What kind of instruction do you design to achieve the aforementioned goals?
- How does students' prior learning affect your instruction designed to achieve the aforementioned goals?
- What kind of difficulties you may have during your instruction?
- How do you assess whether your students achieved the aforementioned goals?
- Until now, what did you learn from this lesson about science/chemistry teaching?
- Are you going to use what you learned from this class when you teach chemistry in future? Please explain your reasoning.

Along with these questions, new questions were asked to pre-service chemistry teachers after PCK for NOS instruction as:

- What did you learn about science/chemistry teaching in last four weeks (PCK for NOS instruction)?
- Did what you learned in the last four weeks change your point of view about science/chemistry teaching? Please explain your reasoning.
- Are you going to use what you learned in the last four weeks when you teach chemistry? Please explain your reasoning.

The second open-ended question contained several sub-questions as indicated in Figure 7 with pre-views 1, 2, 3, and 4 and were different for each PCK for NOS class. These questions were aimed to reveal pre-service chemistry teachers' knowledge and ideas related to each PCK for NOS component; namely, STO, KoL, KoIS, and KoA. Table 6 displays open-ended questions corresponding to each PCK component.

Table 6. Pre-questions asked before each PCK for NOS instruction class

PCK Component	Open-ended questions
STO	• As a teacher candidate, in your view, what is the goal of science education and specifically chemistry education? • As a teacher, in your view, what kinds of knowledge, skills etc. a student should have as a result of science and especially chemistry teaching?
KoL	• What might your students already know about NOS? • Why do you think that they might know that? • Where do you think they might have learned these?
KoIS	• What kind of instructional strategies do you use for teaching NOS and chemistry concepts at the same course hour?
KoA	• Help a teacher who has difficulty in assessing his objectives given in the activity sheet

3.5.3. Reflection Papers

After each PCK for NOS class, pre-service chemistry teachers were asked to write reflection paper to determine the effect of each class on participants' knowledge of each related PCK for NOS component, as indicated in Figure 7 with reflection paper 1, 2, 3, and 4. The questions were the same for each class as:

- What is the message that this lesson want to give? What did you learn about chemistry/science education?
- How did this lesson change your perspective on chemistry/science education?
- How do the things you learned in this lesson affect your chemistry/science teaching?

3.5.4. Lesson Plans

Two lesson plans were collected, as indicated in Figure 7 by lesson plan 1 and 2, in order the understand the nature and development of pre-service chemistry teachers' PCK for NOS . Right after completion of learning NOS part and just before the PCK for NOS instruction, the participants were asked to prepare a lesson plan, as indicated by lesson plan 1 in Figure 7 and from now on will be named in this way. This lesson plan 1 was also helpful for providing supporting evidence or counter evidence for the view that even if teachers have informed understanding of NOS consistent with reforms; they generally do not explicitly teach NOS (Schwartz & Lederman, 2002). Several chemistry topics were assigned to the participants and there were more than one participant preparing a lesson plan on the same chemistry topic. The chemistry topics were:

- Particulate nature of matter
- Atom
- Solutions
- Mole
- Periodic table
- Chemical bonds
- Gases
- Chemical reactions
- Rate of chemical reactions
- Chemical equilibrium
- Acids and bases
- Electrochemistry
- Radioactivity

The participants were free to teach the concepts they wanted to focus in their topics and they were not told that they should integrate NOS into their instruction. A lesson plan format (Appendix E) including several parts such as general and specific objectives, teaching strategy, detailed explanation of their instruction, and assessment were given to pre-service chemistry teachers. After completion of lesson plan 1, PCK for NOS instruction started. After PCK for NOS instruction, pre-service chemistry teachers were asked to revise their lesson plan 1. The participants were not told to integrate NOS during the revisions although they were expected to do so. These revised lesson plans were indicated as lesson plan 2 in Figure 7and from now on will be named in this way. The lesson plan 2 was used to determine how PCK for NOS instruction assisted pre-service chemistry teachers in translating their NOS understanding into their lesson plans.

3.5.5. Interviews

Interviewing is one of the data collection methods that are used when "we cannot observe behavior, feelings or how people interpret the world around them" (Merriam, 1998, p. 72). Therefore, this technique provides opportunity to compensate the limitations of the use of documentary types of sources as VNOS-C, open-ended questions, reflection papers, and lesson plan 1 and 2. Interviewing is helpful in understanding what is in someone else's mind. Two types of semi-structured interviews were conducted in this study. The first one was conducted with nine participants in order to understand the meanings they ascribed to NOS aspects. Lederman et al. (2002) advocated that follow-up questions, directed after completion of VNOS-C, were helpful in clarifying ambiguities and understanding respondents' thinking on NOS aspects. During those interviews, respondents are provided their questionnaires and asked to explain and justify their responses. The second type of interview, therefore, was conducted after PCK for NOS instruction with nine participants in order to gain an in-depth understanding of their PCK development and how PCK for NOS instruction contributed to this development (Appendix F). Several examples for the interview questions are as;

1. Was there any change in your views about what you expect from students to learn about chemistry before NOS instruction, after NOS instruction, and after PCK for NOS instruction? If yes, how?
2. Do you think that your students should learn NOS? Was there any change in your views before NOS instruction, after NOS instruction, and after PCK for NOS instruction? If yes, how?
3. What kind of instructional strategies would you use or did you use to teach NOS? How did learning NOS part and PCK for NOS part contribute to your knowledge of instructional strategies? Which instructional strategies are more affective than others? Please, explain why.
4. How did you determine whether your students had informed undertanding about NOS related objectives? What kind of assessment method would you or did you use? How did learning NOS part and PCK for NOS part contribute to your knowledge of assessment?

3.5.6. Participant Observation

The purpose of observation is to make in-depth and detailed explanations and descriptions about the phenomenon being investigated (Patton, 2002). Participant observation is a type of observation where researcher is not a passive observer rather s/he may take various roles and even may participate the events being studied. In this study, participant observation technique was used as one of the data collection sources since I participated to all the course activities. The Research in Chemistry Education course was the context for TUBITAK project and I was a researcher in that project. More importantly, the research team had the responsibility in conducting all the course activities, which mainly constituted each class's content (what to teach and how to teach) and teaching. In each class, the research group of two or three was the leader in conducting all the course activities. However, the other researchers were also responsible during the guidance provided to small group discussions. As well as I had many opportunities to teach NOS to that group of participants before PCK for NOS instruction, I conducted all the classes took place in PCK for NOS instruction. All the class sessions were videotaped with the permission of the participants. These participant observations enabled me to realize how actually PCK for NOS works (Flick, 2006). The participant observation was used as a complementary data source rather than a primary one. Since I did not have a change to conduct interviews with all participants, I used my participatory observations to increase the credibility of reflection papers that each participant wrote after each PCK for NOS class.

3.6. Pilot Study

I conducted a pilot study with nine pre-service chemistry teachers (six male, three female, M=25) enrolled to "Methods of Science and Mathematics Teaching II" at a public university in Ankara during 2009/2010 fall semester. Doing a pilot research helped me to revise and refine both PCK for NOS instruction and instruments (Marshall & Roseman, 2006). None of the nine participants took any formal course and had personal interest in NOS. During the pilot study, NOS instruction spanned four weeks period (16 class hours) while

PCK for NOS instruction lasted three weeks (12 class hours). The same data collection sources were used: VNOS-C, lesson plans prepared before and after PCK for NOS instruction, responses to open-ended questions given at the beginning of each PCK for NOS class, reflection papers at the end of each PCK for NOS class, and interviews. The pilot study informed me about several things: First, I realized the activities that I prepared for STO, KoIS, and KoA did not work the way I intended to. Therefore, I revised them all those activities. Second, I noticed that the participants were having difficulty in realizing the relevance of PCK for NOS instruction to their future as a chemistry teacher. Therefore, I was more explicit in the way that I connected PCK for NOS components to their chemistry teaching.

3.7. Data Analysis Procedure

Data analysis is the process of making sense of data and hence arriving reasonable conclusions (Merriam, 2002). In contrast to quantitative analysis, there is no formula for transforming data into findings during qualitative data analysis as emphasized by Patton (2002) as "Qualitative analysis transforms data into findings. No formula exits for that transformation. Guidance, yes. But no recipe… [T]he final destination remains unique for each inquirer, known only when-and if- arrived as" (p. 432). In this study, the analytic procedure proposed by Marshall and Rossman (2006) was followed in analysis of the data. The analytic task of qualitative researchers includes two basics parts: data analysis and data interpretation (Bogdan & Biklen, 2007). Data analysis refers to the process of "…working with data, organizing them, breaking into manageable units, coding them, synthesizing them, and searching for patterns" (p. 159). Data interpretation involves explaining findings by relating to theory, showing why findings are important and making them understandable. Analytic procedures consist of seven main phases (Marshall & Rossman, 2006):

- Organizing the data: It includes arranging the huge piles of data in a way that researcher can easily handle the data (e.g., organization can be made considering names, places, date, and activities). In this study, two main electronic files were formed for organizing the data on participants' NOS understanding and PCK for NOS. Also, in the file created for PCK for NOS data, there were three sub-files; one was containing the data of each PCK component interested in this study (e.g., KoL, KoIS, KoA, and STO), one was for lesson plans, one was for interviews. Each PCK for NOS component sub-file included all participants' reflection papers, answers to open-ended questions, and participatory observational field notes.

- Immersion in the data: It is a process of becoming familiar with the data through reading and rereading it. In the present study, after organizing the data into files, all the data including lesson plans, reflection papers, answers to open-ended questions, and participatory observational notes were read and reread for ensuring familiarity.
- Coding the data: Coding is the process in which a name is given to the meaningful part (e.g., a word, sentence, and paragraph) among the data at hand (Marshall & Rossman, 2006). Coding process requires separating into parts, investigating, comparing, conceptualizing and associating the data. Codes can be derived from the researcher himself/herself, the related literature or the data itself. The codes used in this study directly came from the literature on NOS and PCK for NOS. Magnusson et al.'s (1999) PCK model and its components provided the codes in this study as STO, KoL, KoIS, and KoA while change in participants' understanding about NOS was categorized as naive, transitional, and informed (Khishfe & Lederman, 2002).
- Generating categories and themes: After coding the data, categories and themes explaining the codes generally should be built. Categories should be internally consistent but at the same time different from each other. Category and theme generation can be indicative or deductive (Patton, 2002). Inductive analysis is the process of discovering patterns, themes, and categories in data whereas deductive one uses already existing framework to describe categories and themes. Inductive analysis relies on "analyst-constructed typologies" which are created by researchers and not explicitly used by participants (Marshall & Rossman, 2006, p. 458). After coding the data in this study, as literature suggested, I focused on the interaction among the components (Abell, 2008) in order to understand the quality of PCK (Friedrichsen et al.,

2009; Magnusson et al., 1999; Park & Oliver, 2008a). The category of integration came directly from the literature, hence ensured conducting deductive analysis. However, all the new sub-categories under the category of integration emerged inductively when the data on PCK for NOS were analyzed, which will be explained later in detail: (a) the degree of integration among PCK components, (b) the frequency and nature of connections, (c) connections evident in application versus evident in knowledge only, and finally (d) the power of connections among the participants in the same category.

- Offering interpretations: Interpretation is the process of bringing "…meaning and coherence to the themes, categories, developing linkages and a story line that makes sense and is engaging to read" (Marshall & Rossman, 2006). In this phase, the researcher must have to give meanings to the data at hand, explain the relationships among findings, establish cause-effect relationships, arrive some conclusions based on the findings, and finally provide explanations for why the findings are important.
- Searching for alternative understandings: This phase includes looking for alternative explanations different than the ones used to interpret the data and providing reasonable explanations for why the existing explanation is more plausible than the alternative ones. In this study, Magnusson et al.'s (1999) PCK model was the guiding framework for designing both activities in PCK for NOS instruction and data collection sources considering the evidences about the applicability of it for PCK for NOS (Hanuscin & Hian, 2009; Hanuscin et al., 2011). Therefore, components in that model were analyzed. Additionally, analyzing each component and presenting them would not enough to capture the complexity of PCK, how the components were integrated was analyzed, which was recommended by PCK literature (Abell, 2008). After formation of PCK for NOS profile for each participant, the participants' maps were constantly compared and new categories emerged for explaining the differences among the participants:(a) the degree of integration among PCK components, (b) the frequency and nature of connections, (c) connections evident in application versus evident in knowledge only, and

finally (d) the power of connections among the participants in the same category. Those new categories did not exist before the analysis begun and came out as a result of analysis as I searched for an alternative explanation on the participants' PCK for NOS.

- Writing the report: The researcher must write a report which is reasonable (relating it to the literature), appropriate for the experiences of individuals (using terminology which is understandable by the readers), plausible (providing the warrants behind the ideas presented), significance (presenting conclusions and implications for the next research), and readable (using logical, clear, and fluent language). In this study, the report was written by relating it to the NOS, PCK, and PCK for NOS literature, using the terminology in those literature, supporting findings and conclusions with the data in hand, and providing conclusions and implications for NOS and PCK for NOS practices and research.

Additionally, different techniques were employed for analyzing the change in participants' NOS views and PCK for NOS. In the following parts, the techniques used for different part data will be explained in detail.

3.7.1. Analysis of the Changes in NOS Views

VNOS-C (Lederman et al., 2002) was the main data source during the analysis of the change in participants' NOS views. In order to identify participants' NOS views before and after NOS instruction, data obtained from VNOS-C and follow-up interviews were analyzed using analytic induction (Strauss & Corbin, 1998). Analytic induction involves both inductive and deductive analysis (Patton, 2002). In deductive phase, the researcher examines the data using an already existing framework and then during the inductive phase the researcher looks through the data again to see whether there are undiscovered pattern. In the present study, in the deductive phase of analytic induction, already existing categorization proposed by Khishfe and Lederman (2002) was used for identifying participants' NOS views before and after NOS instruction. Khishfe and Lederman (2002) advocated that that there is a continual change in students' understanding about NOS. This continuum begins with naïve, continues with transitional, and ends with informed. Considering this continuum, pre-service chemistry teachers' NOS understandings was categorized as naive, transitional, and informed. Each NOS aspect addressed in this study was evidenced itself in more than one data source (interview and VNOS-C) and moreover, in more than one item in VNOS-C. A participant's view on a particular aspect was categorized as informed if s/he had provided evidence of meaningful understanding related to that aspect in all contexts. If a participant had not exhibited any meaningful understanding with respect to a particular aspect in all contexts, his/her view of the related aspect was categorized as naïve. If a participant had demonstrated meaningful understanding of a particular aspect in some contexts but not the others, his/her view in that aspect was categorized as transitional. Each participant's view was categorized considering the aforementioned categorization and the data related to participants' NOS views were looked through again to see whether there were undiscovered patterns, which formed the inductive phase of analytic induction. That is, in this study analytic induction involved formulating an initial definition of the phenomenon, investigating some cases of this phenomenon, framing a hypothetical explanation, investigation of further cases to test the hypothesis, reformulating the hypothesis or reducing the phenomenon if the hypothesis does not fit, and implementing this cycle of analysis until the point that it may be concluded that the hypothesis is correct (Punch, 2005). An example of categorization for theory-laden NOS aspect is given in Table 7. How we ensured validity and reliability will be discussed in the following part under the heading of validity and reliability issues of the study.

Table 7. An example of categorization for theory-laden NOS aspect

Level	Example statements
Naive	Scientific knowledge is objective. Science should not be affected from these terms. There is only one truth. That truth does not change from place to place and person to person. But physics, biology…. objective. We could not talk about subjectivity. Investigations are scientific studies based on experiments, observations
Informed	Scientists are affected from their own experiences, existing knowledge, and beliefs while explaining a phenomenon. Since scientists' personal characteristics, point of views, interpretations, beliefs are different from each other there are two hypotheses [related to extinction of dinosaurs]. It stems from the differences in scientists' existing knowledge. Individuals having different majors in different disciplines develop different point of views for the situations they encountered and look differently [to the same phenomenon] hence forms different hypothesis. Scientists can reach different findings based on their existing knowledge, the social and cultural environment they live when they use the same data

3.7.2. Analysis of Participants' PCK for NOS

Lesson plan 1 and 2, reflection papers written at the end of each PCK for NOS class, responses to open-ended questions given at the beginning of each PCK for NOS class and after PCK for NOS instruction, and interviews conducted with nine participants were the main data sources during analysis of pre-service chemistry teachers' PCK for NOS. This analysis involved both deductive and inductive analysis as it is the case for some qualitative analysis (Patton, 2002). In the first phase, deductive analysis was conducted where the data was analyzed according to an existing framework, which was Magnusson et al.'s PCK model (1999) in this study (Patton, 2002). All the main aforementioned data were analyzed for the how PCK for NOS components, which are STO, KoL, KoIS, and KoA, indicated themselves in these data sources. After completion of deductive analysis for individual PCK for NOS components, since it is strongly recommended that researchers must focus on the interaction among the components (Abell, 2008) in order to understand the quality of PCK and a teacher's PCK highly depends on the degree of integration and coherence among components (Park & Oliver, 2008a; Friedrichsen et al., 2009), the integration among PCK for NOS components were determined. For determining the consistencies and coherences, a coding scheme was constructed describing instances of integration of components in participants' PCK based. Based on the coding scheme a PCK for NOS map was formed for each participant and then the participants' map compared and contrasted which eventually resulted in new categories, which formed the inductive analysis of data. How deductive and inductive analyses were performed will be elaborated in the following parts. In deductive phase (a) in-depth analysis of explicit PCK (Park & Chen, 2011; Park & Oliver, 2008a) and in inductive phase (b) the constant comparative methods (Glaser & Strauss, 1967) were used in order to delve into the complexities of the nature and integration of participants' PCK for NOS.

3.7.2.1. In-depth Analysis of Explicit PCK

In order to determine the PCK for NOS components which participants developed during PCK for NOS instruction and integration of these components, which referred to connections and consistencies among PCK components addressed in this study, a modified version of in-depth analysis of explicit PCK (Park & Chen, 2011; Park & Oliver, 2008a) was employed during the deductive phase of qualitative analysis. This method mainly relies on creating a PCK profile for each participant providing a detailed description of a pre-service chemistry teacher's PCK for NOS as defined by Magnusson et al.'s (1999) model. Although pre-service chemistry teachers were asked to prepare lesson plan 1 right after the NOS instruction they did not integrate any NOS aspects in their lesson plans. When I asked whether they attempted to teach NOS in their own way, only two participants stated that they tried to teach NOS implicitly by engaging students in an inquiry-based learning setting. Therefore, while the PCK profiles were created, mainly lesson plan 2, reflection papers written at the end of each PCK for NOS class, responses to open-ended questions given at the beginning of each PCK for NOS class and after PCK for NOS instruction, and interviews conducted with nine participants were used as suggested in literature to assess and capture the complexity of PCK (Baxter & Lederman, 1999).

The PCK profile consisted of several components including (see Appendix G for the participants' profiles);

- Chemistry topic on which the lesson plan was prepared
- Objectives including science process skills and NOS aimed to be achieved
- Synopsis of the lesson plan prepared after PCK for NOS instruction
- Evidence for the components of PCK for NOS and connections among them
- A description of where the PCK for NOS components was evident throughout data collection
- Post-intervention PCK for NOS map representing which components and connections and consistencies are present

The final PCK for NOS map included only four components of Magnusson et al.'s (1999) model, namely, STO, KoL, KoIS, and KoA since knowledge of curriculum was not a focus in PCK for NOS instruction. Different types of lines were used to show connections and consistencies among the PCK for NOS components which were evident in different data sources;

- Bold lines for the connections and consistencies that exist in lesson plans
- Solid lines for the connections and consistencies that exist in reflection papers
- Dashed lines for the connections and consistencies that does not exist in any of the data sources

It was obvious that the strength of one connection or consistency between two components might be different from another and it was. Although I assumed the same strength for each connection or consistency for convenience (Park & Chen, 2011) when drawing the PCK for NOS map for each participant, I considered the differences in power of consistencies and connections when presenting the results. In order to decide whether a connection or consistency was evident in any of the data source, a coding scheme was formed. This coding scheme described the instances of PCK components and integration of components in pre-service chemistry teachers' PCK. During the formation of the coding scheme, I relied on the data and literature using in-depth analysis of explicit PCK (Park & Chen, 2011; Park & Oliver, 2008a).

Based on the data and the literature, I defined every possible instance which can be counted as an evidence for any PCK component and consistencies or connections among them (see Table 8). Formation of the coding scheme was accomplished by a researcher who is an expert on both PCK and PCK for NOS by discussing and negotiating any incongruities. For deciding whether the integration between any two PCK components addressed in this study was an indication of consistency or connection, we utilized the PCK literature during the formation of coding scheme. With the recognition of shaping effect of STO on KoL, KoIS, and KoA (Magnusson et al., 1999), any integration between STO-KoL, STO-KoIS, and STO-KoA was coded as consistency. For instance, if a pre-service chemistry teacher used implicit or explicit-reflective instructional approach to teach NOS this instance was counted as an evidence for the consistency between his/her STO and KoIS. On the other hand any integration which was observed any two components of KoL, KoIS, and KoA was coded as connection since each has the capacity to inform other (Abell, 2008) (e.g., KoL might inform KoIS and KoA might inform KoL). For instance, if a pre-service teacher made an assessment to reveal students' misconceptions about NOS at the beginning of his/her instruction this was coded as a connection between KoA and KoL where KoA informed KoL. All the reliability and validity issues regarding the coding scheme formation and coding will be discussed in the following part under the heading of validity and reliability issues of the study.

Table 8. Coding scheme describing instances of PCK components and integration among them

PCK Components	**Instance**	**Consistency or Connection**	**Direction**
STO-KoL	• If pre-service teacher is aware that students have misconceptions in NOS • If pre-service is teaching for one of the myths about NOS (e.g., hierarchical relationship between theory and law)	Consistent	STO influenced KoL
STO-KoIS	• If pre-service teacher uses implicit or explicit approach to teach NOS	Consistent	STO influenced KoIS
STO-KoA	• If pre-service teacher assesses NOS	Consistent	STO influenced KoA
KoA-KoL	• If pre-service teacher makes an assessment to reveal students' misconceptions about NOS at the beginning	Connection	KoA informed KoL
	If pre-service teacher assesses students' misconceptions about NOS s/he communicated in his/her lesson plan at the end	Connection	KoL informed KoA
KoA-KoIS	• If pre-service teacher makes an assessment to reveal students' misconceptions about NOS at the beginning and then designs instruction based on assessment result	Connection	KoA informed KoIS
KoA-KoIS	• If pre-service teacher makes an assessment compatible with the instructional strategy (e.g., relabeling observations and inferences they made at the beginning of the lesson, preparing a poster on their investigation they made throughout the lesson, preparing a periodic table using each group's data)	Connection	KoIS informed KoA

Table 8 (continued)

PCK Components	Instance	Consistency or Connection	Direction
• KoL-KoIS	• If pre-service teacher design an instructional strategy to eliminate students' misconception (paying attention to use of words, after communicating observation and inference using gestalt pictures, after communicating several nature of science aspects asking questions to assess students' understanding and then talking about nature of science whether there is a misconception)	Connection	KoL informed KoIS
	• If a preservice teacher teach for eliminating a misconception (e.g., for eliminating the myth of experiments are not the principal routes to scientific knowledge teacher uses some cases from a science magazine where scientists only use observations or step by step scientific method and makes the students to involve in scientific process)	Connection	KoL informed KoIS

3.7.2.2. The Constant Comparative Method

In the first deductive phase, profiles for each participant and accompanying post-intervention PCK for NOS maps were constructed based on the PCK components defined in Magnusson et al.'s (1999) model and integration defined in PCK literature (Park & Chen, 2011; Park & Oliver, 2008a). In the second inductive phase, constant comparative method (Glaser & Strauss, 1967) was used in order to identify patterns and regularities among the PCK maps without using a pre-established system of categories or codes. Constant comparison method compares incidents in data to develop explanatory categories towards building a theory. This method involves comparing one segment of data with another to determine similarities and differences (Merriam, 2002) and then the data is grouped under similar dimensions. This dimension is tentatively given a name and it becomes a category. All PCK for NOS maps were compared and contrasted with each other in order to identify similarities and differences among them and then eventually to come up with a categorization. As a result of identification of patterns and regularities existed in participants' post-intervention PCK for NOS maps, nine dimensional categorizations were emerged without using an already existing framework for categorization. In the nine dimensional categorizations, there were two main dimensions;

- One dimension showed the degree to which the components are integrated
    - There were four components addressed in PCK for NOS instruction which were STO, KoL, KoIS, and KoA. Therefore, the maximum number of connections/consistencies that could be observed among the components of PCK was six.
    - If the number of consistencies/connections was 5 and 6 in a participant's PCK for NOS map, this participant's PCK for NOS map was categorized as highly-integrated.
    - If the number of consistencies/connections was 3 and 4 in a participant's PCK for NOS map, this participant's PCK for NOS map was categorized as somewhat integrated.
    - If the number of consistencies/connections was 1 and 2 in a participant's PCK for NOS map, this participant's PCK for NOS map was categorized as non-integrated.
- The other dimension indicated the degree to which pre-service chemistry teachers can translate their PCK for NOS into their lesson plan 2, which refers to application in this study.
    - The data for analyzing participants' PCK for NOS mainly were obtained from lesson plan 2, reflection papers written at the end of each PCK for NOS class, responses to open-ended questions given at the beginning of each PCK for NOS class and after PCK for NOS instruction, and interviews. As explained before, different types of lines were used to show connections and consistencies among the

PCK for NOS components which were evident in different data sources;

    - Bold lines for the connections and consistencies that existed in Lesson plan 2
    - Solid lines for the connections and consistencies that existed in reflection papers, responses to open-ended questions, and interviews
    - Dashed lines for the connections and consistencies that did not exist in any of the data sources

- If a participant's PCK for NOS map included one bold line and the rest was solid, this participant's PCK for NOS map was categorized as knowledge.
- If a participant's PCK for NOS map included a mixture of bold and solid lines, this participant's PCK for NOS map was categorized as knowledge-application.
- If a participant's PCK for NOS map included only bold lines, this participant's PCK for NOS map was categorized as application.

All the reliability and validity issues regarding the categorization of participants' PCK for NOS maps will be discussed in the following part under the heading of validity and reliability issues of the study. Examples for the maps included the followings in Figure 10.

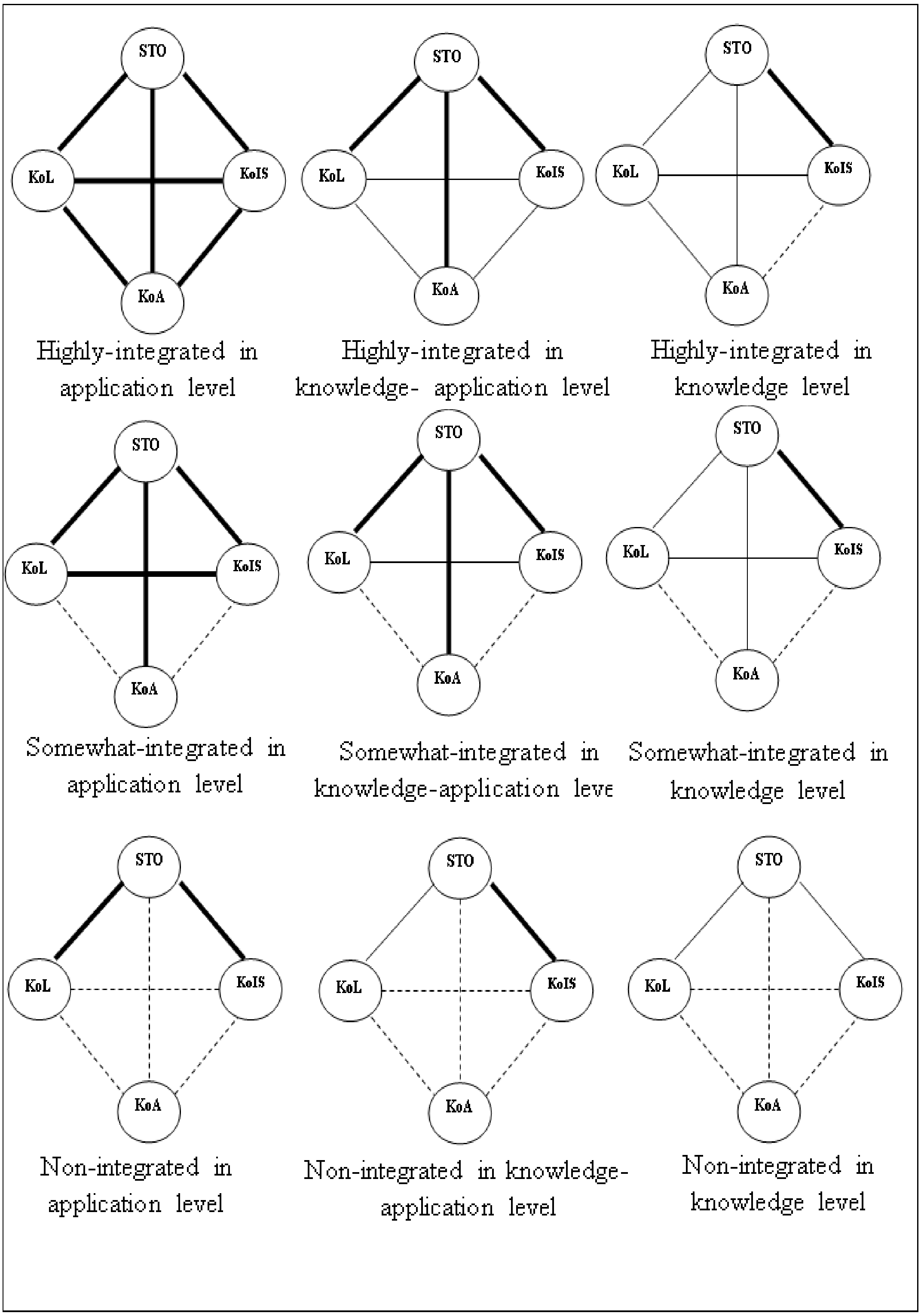

Figure 10. Examples of PCK for NOS map categorized in different groups

3.8. Validity and Reliability Issues of the Study

The consideration of validity and reliability issues in qualitative research is different than its consideration in quantitative research because of the differences in their focus; qualitative research focuses on the existence and meaning of the phenomenon while quantitative research focuses on to what degree the phenomenon exists. These resulted in the use of different terms while talking about the validity and reliability issues in qualitative research (Lincoln & Guba, 1985). Lincoln and Guba (1985) proposed that "credibility" refers to "internal validity", "transferability" refers to "external validity", "dependability" refers to "reliability", and "conformability" refers to "objectivity." They also further elaborated that credibility, transferability, dependability, and conformability ensure trustworthiness. Several techniques were proposed to operationalize these new terms and more importantly to address all these validity and reliability issues in qualitative research. In the following part, how all the validity and reliability issues in this qualitative study, which refers to trustworthiness, were considered will be presented.

3.8.1. Credibility

Credibility in qualitative research refers to what degree the research results are congruent with the reality, which is the phenomenon being investigated (Merriam, 1998). "Credibility requires establishing results in a way that is credible from the perspective of participants and the goal is to demonstrate that the study was conducted in such a manner as to ensure that the subjects was appropriately identified and described" (Marshall & Rosmann, 2006, p. 201). There are several techniques increasing the credibility of qualitative research, namely, prolonged engagement, triangulation, peer debriefings, member checks, participatory modes of research, and clarifying researcher's biases. In this study, triangulation, prolonged engagement, peer debriefings, and member checks were used to ensure credibility.

Triangulation refers using different data sources of information by examining evidence from the sources and using it to build a coherent justification for themes (Creswell, 2007). Patton (2002) defined four kinds of triangulation adding to the credibility; methods triangulation, triangulation of sources, analyst/investigator triangulation, and theory/perspective. Triangulation of sources and analyst/investigator triangulation were used to increase credibility. Multiple data sources including VNOS-C, lesson plan 1 and 2, reflection papers written after each PCK for NOS class, responses given to open-ended questions after NOS instruction, before each PCK for NOS class, and after PCK for NOS instruction; interviews conducted after completing VNOS-C and PCK for NOS instruction; and videotaped records of observations were used to achieve triangulation of sources in the current study.

Analyst/investigator triangulation requires using multiple observers, interviewers, and analysts instead of one and it was ensured by several ways. Throughout all data collection process, at least three researchers who were familiar with NOS and PCK were participated all the classes during NOS and PCK for NOS instruction. During the analysis stage, two analysts, among those researchers, independently coded the data for NOS and PCK for NOS after forming a rubric for NOS and a coding scheme for PCK for NOS. Moreover, four researchers who were studying PCK individually compared participants' PCK for NOS maps and then reached a consensus on categories inductively derived from data. The rubric for NOS directly came from NOS literature (Khishfe & Lederman, 2002) and the coding scheme used for creating PCK for NOS profiles including participants' maps was formed by me and a researcher who is an expert on both PCK and PCK for NOS by discussing and negotiating any incongruities. After formation of the rubric and coding scheme, two independent researchers coded the data for NOS and PCK for NOS. The incongruities between researchers were resolved by negotiation and discussion.

Prolonged engagement is achieved by being present in the research site for an extended period of time. The more researcher engages with the reality, the less s/he affects the setting and in addition the more s/he can reach the reality. I spent a whole year, including two semesters, within this research setting and with this participant. I participated all the classes during NOS and PCK for NOS classes. Most of the time, I was one of the leading instructor of the class and had a chance to observe and talk with participants in and out of the class settings.

Peer debriefing involves locating a person who reviews and asks questions about qualitative study (Marshall & Rossman, 2006). I consulted two of my colleagues who had experience in qualitative research and were studying NOS and PCK during collecting, coding, analyzing and interpreting the data.

Member check is the most essential technique for establishing the credibility of the study (Lincoln & Guba, 1985). It refers to make the participants of the study check the data, categories and interpretations (Creswell, 2003). After completion of analysis of data, one of the profiles created for the participant's PCK for NOS were printed out and the participants were asked to check the data, categories and interpretations.

Although all the aforementioned efforts enhance credibility, Patton (2002) advocated that credibility in qualitative research also depended on "the credibility of the researcher and philosophical belief in the value of qualitative inquiry" (p. 552). Credibility of the researcher is related to researcher's "training, experience" (p. 552) while philosophical belief in the value of qualitative inquiry refers to "…fundamental appreciation of naturalistic inquiry qualitative methods, inductive analysis, purposeful sampling, and holistic thinking" (p. 553). Before this study, I took a course on qualitative research. Also, I was involved in various researches on NOS, PCK, and PCK for NOS both in Turkey and USA. All these evidences helped me to increase my credibility as a researcher on PCK for NOS.

3.8.2. Dependability

The issue of reliability should be considered in two contexts within qualitative research. First, if multiple data are used, are they internally consistent? In this study, various data sources including lesson plans, reflection papers, responses to open-ended questions, and interviews were used and all these data sources were internally consistent with each other. Second context is related to the process of data analysis; inter-coder agreement. In this study, inter-coder agreement was achieved for both analysis of the change in participants' NOS views and PCK for NOS. For NOS, two researchers who have experience on NOS, chemistry education, and qualitative research coded the NOS data for 25% of VNOS-C. For PCK for NOS, two researchers who have experience on NOS, chemistry education, PCK, PCK for NOS, and qualitative research coded the PCK for NOS data for five participants. Inter-rater reliabilities were calculated for NOS and PCK for NOS in order to enhance credibility. The formula proposed by Miles and Huberman (1994) was used during calculation as;

Reliability = Number of agreements/
(Total number of agreements + disagreements) X 100

Inter-rater reliability was calculated as 95% for NOS and %90 for PCK for NOS. The inconsistencies between coders were resolved by negotiating and discussing.

3.8.3. Transferability

Transferability refers to what extend the findings of the study can be useful to others with similar research questions (Lincoln & Guba, 1985). In order to show the degree to which the results of this study can be useful in other settings thick description was used. Thick description requires providing a description rich enough to permit the reader to determine how well this study transfers to other similar situations (Patton, 2002). The physical and cultural environment of the college of education, chemistry teacher education program, participants, and the context where NOS and PCK for NOS instruction conducted were described in detail.

Until now, how the validity and reliability issues ensured were discussed in detail. In the next parts**,** data base search, role of the researcher, ethical issues, and schedule will be explained in detail.

3.9. Key Words and Databases Searched

Key terms were determined based on the literature. Although chemistry teacher education was the major concern, both pre-service and in-service science teachers were used as key words in addition to chemistry teachers since NOS is above the particular discipline in science. The key terms used in this study were NOS, PCK, PCK for NOS, pre-service science teachers, in-service science teachers; pre-service chemistry teachers, and in-service chemistry teachers. Among the databases Science Direct, Educational Resource Information Center (ERIC), and International Dissertation Abstract were searched for general and reaching primary sources were searched. Various journals in Turkey, having online access, were also searched to reach the primary sources such as. Hacettepe University Journal of Education, Education and Science, and Elementary Online, Çukurova University Journal of Education, Kastamonu Education Journal, Gazi University Journal of Education, Eurasia Journal of Mathematics, Science and Technology Education, Eurasian Journal of Educational Research, and Educational Science: Theory and Practice) were searched. In addition to databases, I searched the various libraries in different universities (e.g., Middle East Technical University, Gazi University, and University of Missouri) in order to reach the books. The literature review is a never ending process and it continued throughout all the phases of dissertation. After completion of literature reviews, all the primary sources were read by noting relevant key points.

3.10. The Role of the Researcher

In qualitative research, since the researcher is the key instrument (Marshall & Rossman, 2006) s/he should explain his/her role. Patton (2002) proposed a continuum describing the researcher’s role in a qualitative research; participantness, revealedness, intensiveness, and extensiveness.

The degree of participantness ranges between full participant and complete observer. In between the two, the researcher might take several roles including the characteristics of both observer and participant. Participant observation is a type of observation where the researcher is not a passive observer rather s/he may take various roles and even may participate the events being studied. In this study, I was participant observer since I conducted all the course activities, which were mainly preparing each class's content (what to teach and how to teach it) and teaching. In each class, the research group of two or three was the leader in conducting all the course activities. However, the other researchers were also responsible during the guidance provided to small group discussions. As well as I had many opportunities to teach NOS to that group of participants before PCK for NOS instruction, I instructed all the classes took place in PCK for NOS instruction. These participant observations enabled me to realize how actually PCK for NOS works (Flick, 2006).

Revealedness is related to participants' awareness about there is an ongoing study and ranges between full disclosure and complete secrecy. The course formed the context for both this study and TUBITAK project. At the beginning of the 2009/2010 academic year, principal investigator introduced the project and researchers to the participants. Also, participants were asked to sign a consent form and all participants voluntarily signed the form. The course spanned two semester and the participants already got used to be involved all class activities and be recorded by video camera during PCK for NOS instruction which implemented in second semester.

Intensiveness and extensiveness is related to the amount of time that researcher spend in the context (Marshall & Rossman, 2006). As I explained before, I participated all the classes in NOS and PCK for NOS instruction, spanned two semesters. During these classes, sometimes I taught or co-taught the classes. Therefore, the participants perceived me as one of their teachers rather than one of the researchers. Hence, in this study, I had enough time to build trusting relations with the participants.

3.11. Negotiating Entry

"Research on Chemistry Education Course" was elective and all the participants voluntarily took the course knowing that they would gain new insights on chemistry education. Moreover, they knew that this course would be different in terms of coursework from other courses in their program. At the beginning of the course, all participants were informed about the TUBITAK project and the course requirements. Before the PCK for NOS instruction begun, I had explained my research to the participants honestly and the participants voluntarily involved in all the activities.

3.12. Ethical Considerations

Ethical standards were taken into consideration from the beginning of the study to the end. First of all, I applied to Institutional Review Board (IRB) permission and it had been taken before the study begun (Appendix H). IRB acknowledged that participants would be fully aware of the purpose and no potential risk or harm involved in the study. Anonymity of the participants and the university were ensured. Pseudonyms were used for all the participants and all the participants voluntarily accepted to participate in the study by signing a consent form. In this consent form and at the beginning of the course, the participants were informed about the purpose of the study. Also, nobody except the researcher, supervisor, and coders had access to the data. Hence, all the issues regarding ethics in research, namely, deception of the participants, protection of the participants from harm, and confidentiality were assured (Frankel & Wallen, 2006).

3.13. Limitations and Trustworthiness of the Study

There are two limitations which are inherent to the nature of qualitative inquiry. The first one is related to disturbance of natural setting. Existence of researcher and video recording of all classes might have affected the participants' behaviors. However, as I explained before, this study was conducted within a two-semester long course and although participants were informed about the research after a while they perceived me as one of their teacher rather than a researcher. This was because, I taught or co-taught all the classes held during the course. Also, participants never expressed that they had some stress because of the video camera. They behaved whether there was no camera existed. The second one is related to generalizability of the study. The participants were typical in the sense that they took similar courses during their teacher education program compared to other chemistry education majors in other universities in Turkey. Also, to the best of my knowledge, I can conclude that these participants were not different from other pre-service science teachers in other European countries and USA based on my readings and experiences in USA. The findings of the study could be transferred into other similar settings. Other limitation in this study was related to the lack of several data sources. This study lacked of interviews associated with pre-service teachers' reasoning behind their lesson plans. There are several ways in compensating the absence of interviews such as using Content Representation Tools (CoReS) and Pedagogical and Professional-experience Repertoires (Pa-PeRs) (Loughran et al., 2008). In this study, reflection papers were used in that sense since participants provided explanations about their possible actions. Moreover, during the analysis and interpretation of data, I differentiated participants provided evidence about their PCK for NOS in their reflection papers (labeled as knowledge level) from the ones who translated their PCK into their lesson plans (labeled as application level).

3.14. Time Schedule

Data were collected from 30 pre-service chemistry teachers enrolled to an elective "Research on Chemistry Education Course" in a public university in Ankara. Table 9 shows the timeline of the research.

Table 9. Timeline for the research

Date	Events
June 2008 – December 2008	Design of the study
December 2008 – September 2009	Development of activities and data collection sources
September 2009 – December 2009	Piloting the study
December 2009 – March 2010	Data analysis of the pilot study and revision of the activities and instruments
March 2010 – July 20010	Data Collection
August 2010 – August 2011	Data Analysis
August 2011 – November 2012	Writing results, conclusion, and discussion section

3.15. Assumptions of the Study

There were several assumptions inherent to the study;

- Participants are information rich cases.
- Participants have enough SMK about the topic they prepared lesson plans.
- Having inadequate understanding of NOS is a pre-requisite for developing PCK for NOS.
- Reflection papers provided the pre-service teachers' reasoning behind their lesson plans.
- Assuming the same strength for different connections between any two components for convenience at the beginning of analysis but later focusing on the differences among the participants by elaborating the power of connections and hence tackled with this limitation

CHAPTER IV

RESULTS

In this chapter, results are presented under three main parts: the change in pre-service chemistry teachers’ NOS understanding, development of their PCK for NOS, and lastly the relationship between pre-service chemistry teachers' NOS understanding and their PCK for NOS. Each part provided the answers for sub-problems of the main research question, which is “How is pre-service chemistry teachers’ PCK for NOS including STO, KoL, KoIS, and KoA developed throughout PCK for NOS instruction?” The change in pre-service chemistry teachers’ NOS understanding part answered the sub-problems of “What kinds of views do the preservice chemistry teachers have on the NOS concepts before explicit-reflective NOS instruction?” and “What kinds of views do the preservice chemistry teachers have on the NOS concepts after explicit-reflective NOS instruction?” Development of pre-service chemistry teachers’ PCK for NOS provided answers to the sub-problems of “Which components of PCK for NOS do pre-service chemistry teachers develop throughout PCK for NOS instruction? How and to what degree do pre-service chemistry teachers translate PCK components into their lesson plans?" and How and to what degree do pre-service teachers integrate the components of their PCK for NOS?” Relationship between pre-service chemistry teachers’ NOS understanding and their PCK for NOS part included the answer given to the question of “How are pre-service chemistry teachers’ NOS understanding and their PCK for NOS related? ”

4.1. The Change in Pre-service Chemistry Teachers’ NOS Understanding

VNOS-C in conjunction with follow-up interviews was used as main data collection source in identifying how pre-service chemistry teachers’ NOS views changed. Considering the administration of VNOS-C at several times and there are some missing data in second administration of VNOS-C, the change in participants' NOS understanding was presented under several sub-parts;

- the participants' NOS views before and after the NOS instruction (as indicated by the percentages of their views);
- the change in the participants' views on each NOS aspect before and after the NOS instruction (as indicated by percentages of naïve, transitional, and informed views and supported with the quotes for those views).

Although a a researcher I did my best in collecting data in some of the VNOS-C there were some unanswered items and this caused missing data related to some aspects of NOS. In the first VNOS-C administered before NOS instruction 13.3% of the participants' views in each NOS aspect was missing whereas it was 3.3% in theory and law aspect in the VNOS-C administered after NOS instruction. Therefore, the sum of percentages of participants with naive, transitional, and informed views may not be 100 at all times when percentages were presented. First of all, the overall change in participants' naive, transitional, and informed NOS views before and after the NOS instruction was presented to provide a big picture of the change (see Figure 11). In Figure 11, the percentage of participants with naïve, transitional, and informed NOS views in two administration of VNOS-C instrument was presented independent from the aspects so that how the number of participants with different NOS views changed could be easily realized. There was a gradual increase in the number of participants with informed NOS views (26.2% of participants before and 72.9% after) whereas there was a gradual decrease in the number of participants both with naïve NOS views (32.9% of participants before and 5.2% after) and with transitional NOS views (27.6% of participants before and 21.4% after). It can be concluded that explicit-reflective NOS instruction contributed to pre-service chemistry teachers' NOS understandings.

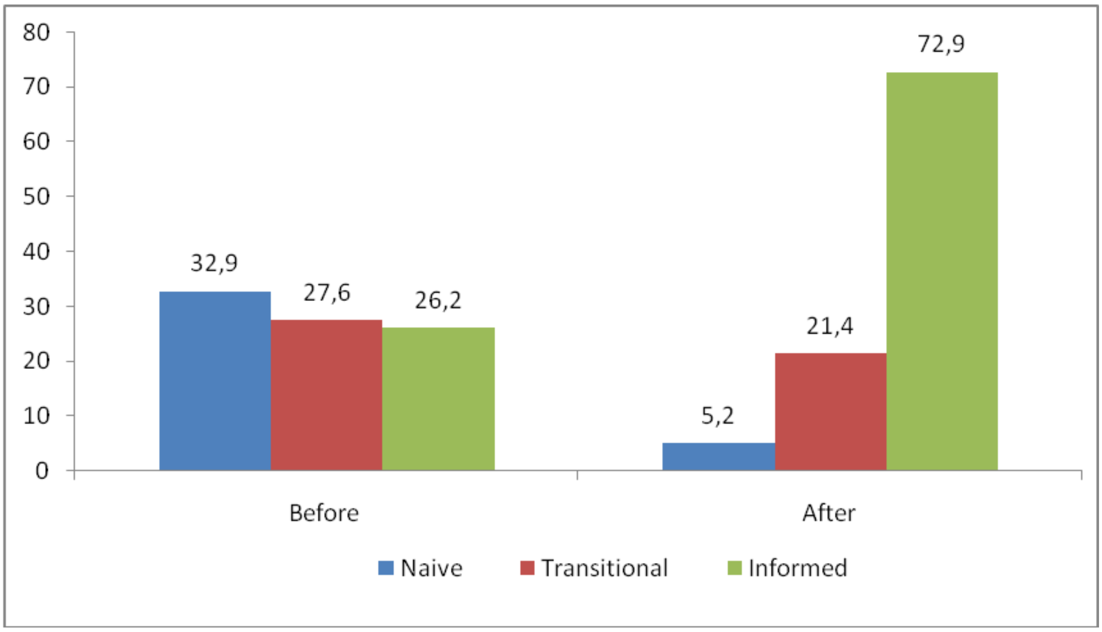

Figure 11. Percentage of participants with naïve, transitional, and informed NOS views before and after NOS instruction

Second, analysis of VNOS-C administered before the NOS instruction indicated that pre-service chemistry teachers had various misconceptions about NOS (e.g., hypotheses become theories that turn into laws, scientists are particularly objective). When all NOS aspects addressed in the NOS instruction was considered, the percentage of naïve (32.9%) and transitional (27.6%) views was 60.5% whereas the percentage of informed views was 26.2% (13.3% of the views was missing). While vast majority of the participants (80%) had naïve view about theory-law aspect of NOS, interestingly no participant had naïve view about creative and imaginative NOS aspect. However, even in the creative NOS aspect where no participants expressed naïve view, 43.3% of the participants had transitional view about the role of creative and imagination in science, which was an evidence for the inconsistency in their NOS views (see Figure 12).

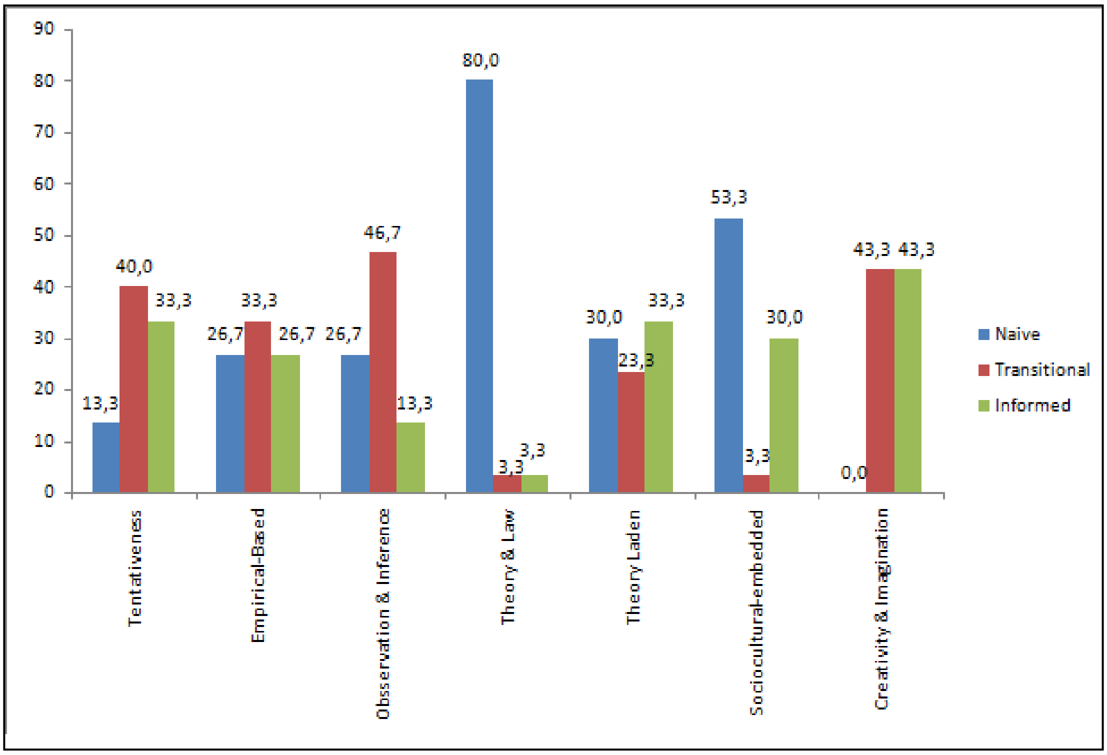

Figure 12. The percentage of participants with naïve, transitional, and informed NOS views in each NOS aspect before NOS instruction

Third, analysis of VNOS-C administered after the NOS instruction indicated that participants' NOS views changed in the desired way; decrease in naïve and transitional views, and increase in informed views (see Figure 13). When all NOS aspects addressed in the NOS instruction was considered, it is seen that the average percentage of transitional and naïve views decreased substantially whereas the percentage of informed views rose to 72.9%. In spite of the increase in informed NOS views, pre-service chemistry teachers still had difficulty in understanding empirical-based (6.7%), and social and cultural embedded NOS (6.7%) as well as the difference between theory and law (13.3%), and observation and inference (10%).

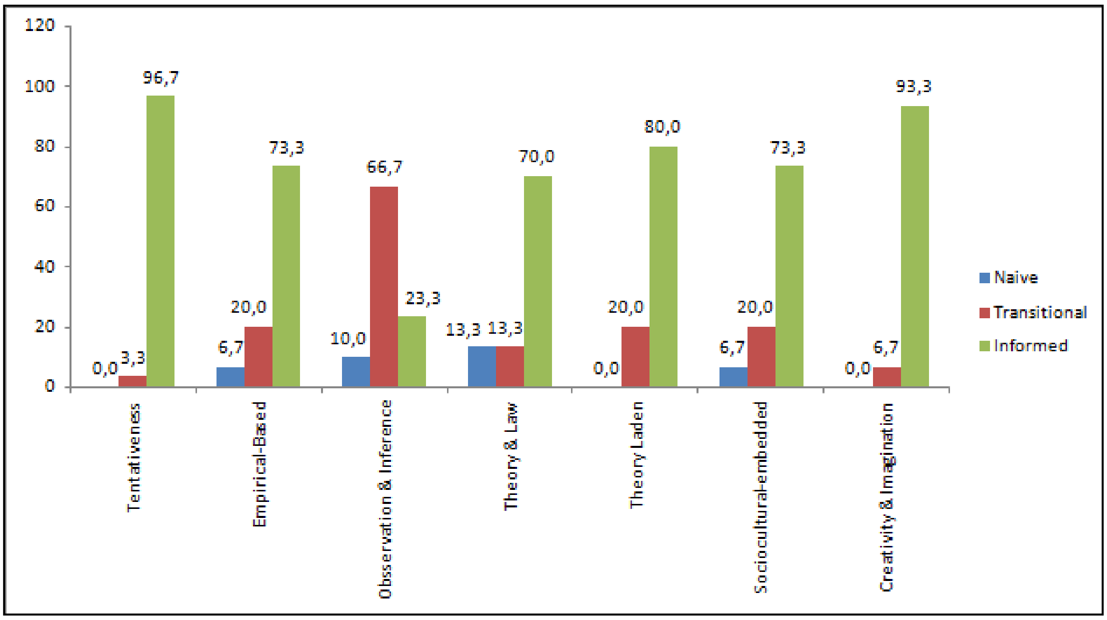

Figure 13. The percentage of participants with naïve, transitional, and informed NOS views in each NOS aspect after NOS instruction

Fourth, to provide a clear picture of how the number of naïve, transitional, and informed NOS views changed throughout the NOS instruction, participants VNOS-C results before, during, and after the NOS instruction were compared (see Figure 14). The comparisons revealed that there were remarkable increases in the number of participants with informed NOS views in each aspect. The most noticeable change was observed in theory and law aspect and this was followed by social and cultural embedded and theory-laden NOS aspects. The number of participants with naïve views decreased in those aspects and those decreases were accompanied by increases in the number of participants with informed views. The least change was evidenced in creative and imaginative NOS aspect since there was no participant with naïve views before NOS instruction.

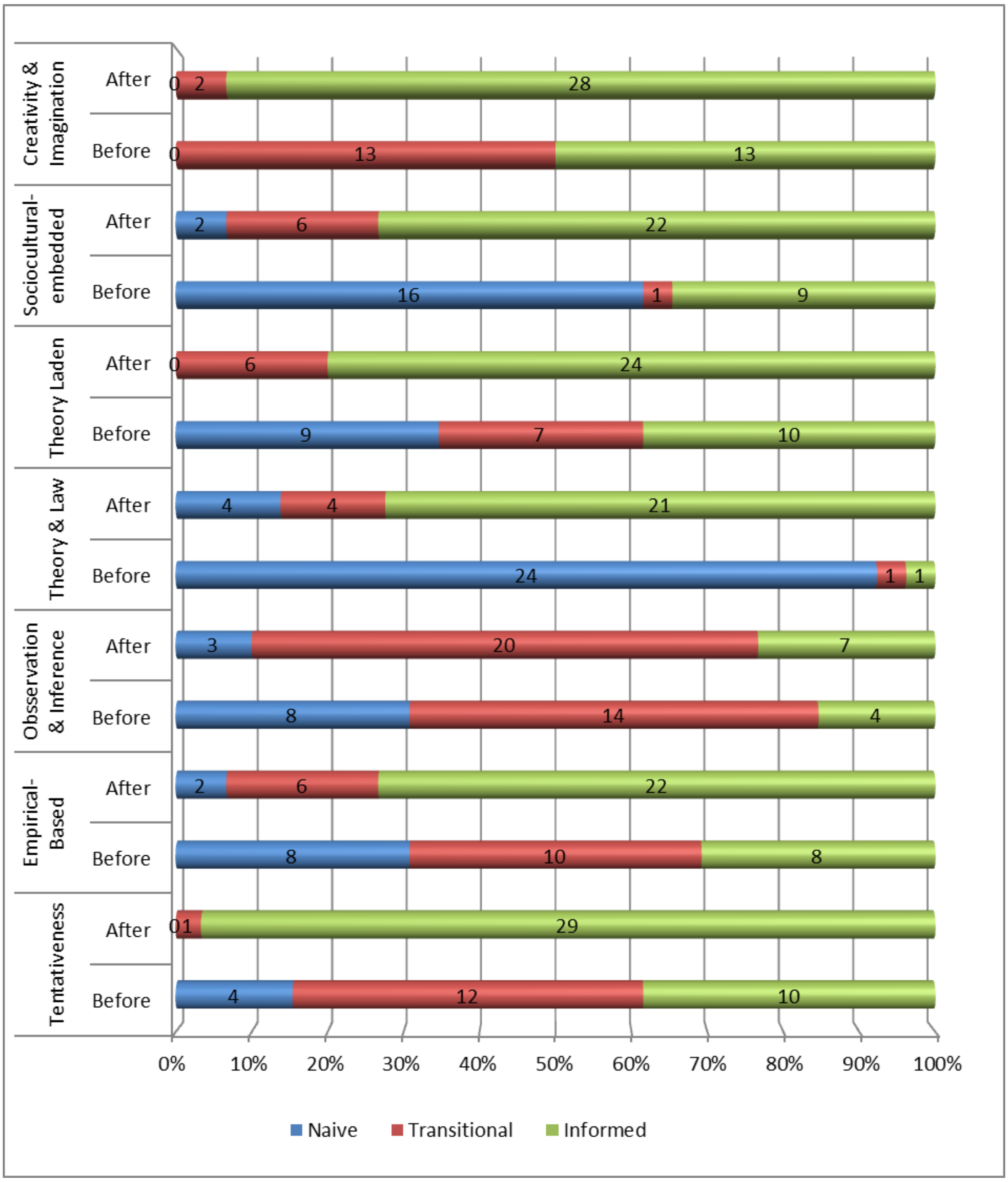

Figure 14. The comparison of VNOS-C results obtained from its administration before and after NOS instruction

Finally, regarding how the participants' NOS understanding changed throughout NOS instruction, in this part, the change in pre-service chemistry teachers’ views on each NOS aspect before, during, and after NOS instruction was elaborated under the sub-headings of NOS aspects.

Scientific knowledge is tentative: Before the NOS instruction, all participants stated that scientific knowledge was tentative. However, most of them explained that laws do not change and are absolute. Therefore, 40% of the views in this aspect were categorized as transitional. A gradual decline was observed in the number of the participants believing that laws are absolute in VNOS-C administered after the NOS instruction. Also, the percentage of transitional views decreased in VNOS-C administered after the NOS instruction and this decrease was accompanied by the increase in the percentage of the participants with informed views (96.7%) (see Table 10). After the NOS instruction, most of the participants expressed that all scientific knowledge could change and there was no place for absolute knowledge in science (see Table 11 for sample statements).

Table 10. The number and percentage of the participants’ views about “tentativeness of scientific knowledge” in VNOS-C administered before and after the NOS instruction

	Time of VNOS-C administration in the NOS instruction	
Views	Before	After
Naive	4 (13.3%)	0 (0%)
Transitional	12 (40%)	1 (3.3%)
Informed	10 (33.3%)	29 (96.7%)

Table 11. Participants' sample statements related to tentativeness of scientific knowledge after the NOS instruction

Level	Sample Statements
Naive	… things that we accepted as laws cannot change in any sense. Scientific theory can change while scientific laws cannot. For instance, Conservation of Mass law is always true and covers all the physical-chemical changes. …laws do not change such as law of gravity
Informed	…science is tentative and can be questioned. It is not static and absolute. If [scientific knowledge] is insufficient in answering questions of humankind in time, it changes. Science does not consist of absolute truths. It can continuously change as a result of researches. Because scientific knowledge can change. But science can be questioned and change. In first place, fundamental base of science is the change.

Science is based on observations and experiments: Before the NOS instruction, only 26.7% of the participants expressed that experiments have important role in science and experiments are not the principal role to scientific knowledge (see Table 12). After the NOS instruction, there was a considerable decrease in the number of participants with naïve and transitional views and almost three quarter of the participants had informed views about this aspect (see Table 13).

Table 12. The number and percentage of the participants' views about "science is based on observations and experiments" in VNOS-C administered before and after the NOS instruction

	Time of VNOS-C administration in the NOS instruction	
Views	Before	After
Naive	8 (26.7%)	2 (6.7%)
Transitional	10 (433.3%)	6 (20%)
Informed	8 (26.7%)	22 (73.3%)

Table 13. Participants' sample statements related to "science is based on observations and experiments" after the NOS instruction

Level	Sample Statements
Naive	If we do not do the experiments, we cannot prove that scientific knowledge is wrong. Whether hypotheses are true or not can reveal only when we conduct experiment. Because we can prove that scientific knowledge is true merely by doing experiments.
Informed	Experiments may not be required to produce every kind of scientific knowledge. I do not thing that scientific knowledge is not produced without doing an experiment. But I believe that experiments are necessary for producing scientific knowledge more easily or developing it. [Science] is a mental activity where data obtained from the experiments are questioned, evaluated, [and] warrants are presented, [and] which is enriched by hypotheses and theories.

Scientific knowledge is based on inferences as well as observations: Before the NOS instruction, majority of the participants had naïve and informed views in this aspect (see Table 14). In other words, the participants did not provide consistent views about the role of indirect evidence in science, the role inferences as well as observations in producing scientific knowledge, and the nature of scientific models (see Table 15). After the NOS instruction, there was an increase in the number of participants with informed views (from 13.3% to 23.3%) bearing in mind that, this increase was not enough as desired.

Table 14. The number and percentage of the participants' views about "scientific knowledge is based on inferences as well as observations" in VNOS-C administered before and after the NOS instruction

	Time of VNOS-C administration in NOS instruction	
Views	Before	After
Naive	8 (26.7%)	3 (10%)
Transitional	14 (46.7%)	20 (66.7%)
Informed	4 (13.3%)	7 (23.3%)

Table 15. Participants' sample statements related to "scientific knowledge is based on inferences as well as observations" after the NOS instruction

Level	Sample Statements
Naive	Science is based on confirmation and proof. Therefore, science reflects reality. For instance, [the idea of] atoms have building blocks was proven. [Scientific knowledge] is verified by observations, proofs. With the electroscopes, [scientists] investigated the smallest building block of matter.
Informed	We said that science progressed systematically. Hence, new data [and] scientific knowledge is produced with the more comprehensive experiments and inferences based on those [experiments] conducted in the light of technological developments. Scientists have been accepted the most valid model about structure of the atom and used it. Still it has not been stated that this model is absolutely true. But it was accepted since that model is the one of which its use is true. Nowadays, various atom models have been developed. But, atom [as we know it today] was modeled with the experiments.

Scientific theories and laws have different roles in science: Before NOS instruction only one participant had informed view about the role of theories and laws in science (see Table 16). Additionally, this aspect is the one of which the participants had the highest number of naïve views when compared to the ones in other aspects of NOS. Most of the participants believed that there was a hierarchical relationship between theory and law as well as theories were not proven and would be laws when proven (see Table 17). Also, they confused law with phenomenon. Naïve views about the role of theory and law in science decreased mostly when compared to the decreases in naïve views in other NOS aspects. However, the percentage of participants with informed views increased to 70% in the VNOS-C administered after the NOS instruction.

Table 16. The number and percentage of the participants' views about "scientific theories and laws have different roles in science" in VNOS-C administered before and after the NOS instruction

	Time of VNOS-C administration in NOS instruction	
Views	Before	After
Naive	24 (80%)	4 (13.3%)
Transitional	1(3.3%)	4 (13.3%)
Informed	1 (3.3%)	21 (70%)

Table 17. Participants' sample statements related to "scientific theories and laws have different roles in science" after the NOS instruction

Level	**Sample Statements**
Naive	Theories can change. If a theory is accepted by all scientists, it turns into law. When it becomes a law, it does not change. Law is an unchanged reality. On the other hand, theory is a knowledge which is not accepted by all scientists and can change with new information. …as it is obvious from its name it is a theory and not absolute. Scientific theories can change in time while scientific laws are accepted without pursuing their change. For instance, theory of evolution is known but not accepted whereas law of gravity is known and accepted. Since whether theories are true or not cannot be completely proved they did not turn into laws and can change.
Informed	Scientific theory explains phenomena. Laws are about the relationships between phenomena. For instance, Law of gravity. Boyle and Charles Laws explain the relationship between variables while Kinetic Molecular Theory explains how the phenomenon occurs. That is the difference between scientific theory and law is not to with one is supported more than the other. There is no hierarchy between them.

Scientific knowledge is theory-laden and includes subjectivity: Before the NOS instruction, almost one third of the participants had naïve view in this aspect stating that science and scientific knowledge is objective, and is not affected by scientist's existing knowledge, attitudes or values. However, there was no participant having that belief in VNOS-C administered after the NOS instruction (see Table 18). Before the NOS instruction, 33.3% of the participants had informed view about theory-laden NOS aspect and there was a remarkable increase in the participants with informed view in this aspect (80% of the participants in VNOS-C administered after the NOS instruction). Most of the participants emphasized that scientists inevitably are affected by their existing knowledge, attitudes, and values after NOS instruction (see Table 19).

Table 18. The number and percentage of the participants' views about "scientific knowledge is theory-laden and includes subjectivity" in VNOS-C administered before and after the NOS instruction

	Time of VNOS-C administration in NOS instruction	
Views	Before	After
Naive	9 (30%)	0 (0%)
Transitional	7 (23.3%)	6 (20%)
Informed	10 (33.3%)	24 (80%)

Table 19. Participants' sample statements related to "scientific knowledge is theory-laden and includes subjectivity" after the NOS instruction

Level	**Sample Statements**
Naïve	Scientific knowledge is objective. Science must not be affected by these terms. There is one reality. That reality does not change from region to region or person to person. But physics, biology…[are] objective. There is no place for subjectivity.
Informed	When scientists propose and explanation about a phenomenon they are affected by their experiences, existing knowledge, and beliefs. Since scientists' personality, point of views, interpretations, and beliefs are different from each other there are two hypotheses It [presence of two theories on extinction of dinosaurs] stems from the differences in scientists' existing knowledge. Individuals having different degrees in various disciplines bring different viewpoints for the events they encountered and hence they propose different hypotheses. Scientists can reach different conclusions even they use the same data based on their existing beliefs, and social and cultural environment they live.

Social and cultural factors affect science: Before the NOS instruction 30% of the participants believed that science was inevitably affected by social and cultural values whereas the percentage of participants with that belief increased to 73.3% (Table 20). About half of the participants (53.3%) stated that science was universal, and not affected by social and cultural factors before the NOS instruction. However, there were only two participants having that belief after the NOS instruction (see Table 21 for participants' statement examples in this aspect).

Table 20. The number and percentage of the participants' views about "social and cultural factors affect science" in VNOS-C administered before and after the NOS instruction

	Time of VNOS-C administration in NOS instruction	
Views	Before	After
Naive	16 (53.3%)	2 (6.7%)
Transitional	1 (3.3%)	6 (20%)
Informed	9 (30%)	22 (73.3%)

Table 21. Participants' sample statements related to "social and cultural factors affect science" after the NOS instruction

Level	**Sample Statements**
Naive	Science is universal. Science is not affected from social and cultural values in any sense. If science is not universal we would be living in Stone Age. There is no true or false and everybody has his/her own idea. We have a proof in hand and we defend it. It is impossible that the proof can be affected from social and cultural values.
Informed	Science reflects the social and cultural values of the society in which it is conducted. Because science is a human endeavor. Social and cultural values direct people's need too. Scientific studies are conducted with the purpose of satisfying those needs. Therefore, I have the belief that scientific studies reflect the social and cultural values. Science reflects the social and cultural values and is affected from them.

Creativity and imagination plays a major role in science: The role of creativity and imagination aspect is the one of which the participants had least difficulty in understanding (see Table 22). Before the NOS instruction, all participants explained that creativity and imagination is important in science and nearly half of the participants believed that creativity and imagination is used in particular phases of an investigation. More importantly, they advocated that scientists must be objective and therefore creativity and imagination is not used in data interpretation (see Table 23). After the NOS instruction, 93.3% of the participants stated that creativity and imagination is important in every phase of a scientific investigation including data interpretation.

Table 22. The number and percentage of the participants' views about "creativity and imagination plays a major role in science" in VNOS-C administered before and after the NOS instruction

	Time of VNOS-C administration in NOS instruction	
Views	Before	After
Naive	0 (0%)	0 (0%)
Transitional	13 (43.3%)	2 (6.7%)
Informed	13 (43.3%)	28 (93.3%)

Table 23. Participants' sample statements related to "creativity and imagination plays a major role in science" after the NOS instruction

Level	**Sample Statements**
Naive	…It is useful to utilize it [creativity and imagination] in the first phase [planning and design of an investigation]. The latter phases [data collection and data interpretation] must be bases on evidence. Scientists use their creativity and imagination after they collect data.
Informed	In every phase [planning and design of an investigation, data collection, and data interpretation] of an investigation, creativity and imagination is used. Scientists put their creativity and imagination into every phase beginning from the observation when they produce scientific knowledge.

Science and technology is not the same thing: Since there was no question related to this aspect in VNOS-C, activity sheets, video recordings of class discussion, and interviews were used as data sources. Analysis of data revealed that the participants had inadequate views about science and technology before the NOS instruction. They stated that science and technology were different from each other but could not explain the difference. Most of the participants (82%) defined technology as the application of science (e.g., machines or computers). After the NOS instruction, only five participants had still that belief about technology whereas others described technology as a technique, process or system directed to satisfy a need. Additionally, 82% of the participants explained the difference between science and technology by differentiating them with regard to purpose, process, and product. All the participants believed that science and technology were closely related both before and after the NOS instruction. However, 61% of the participants thought that a technological development based on a scientific discovery, which was consistent with their belief that technology was an application of science before the NOS instruction. On the contrary, all the participants but three started to think that science is not the only base for a technological development.

4.1.1. The Change in Each Participant's NOS Views with regard to Every Aspect Before and After the NOS Instruction

NOS understanding refers to SMK in this study and is a pre-requisite for a well-developed PCK for NOS (van Driel et al., 1998). Therefore, it is important to analyze how each participant changed his/her NOS views with regard to every aspect after the NOS instruction (see Table 24). Also, those findings will shed light to the findings about the relationship between pre-service chemistry teachers' NOS understanding and their PCK for NOS.

Table 24: The change in participants' NOS views with regard to each aspect before and after NOS instruction

	NOS aspects													
	Tentativeness		**Empirical-based**		**Observation & Inference**		**Theory & Law**		**Theory-Laden**		**Sociocultural-embedded**		**Creativity & Imagination**	
Participants	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Ahmet	I*	I	T	I	I	I	N	I	T	T	I	I	T	I
Ayse	T**	I	T	T	N	I	N	T	N	I	N	I	T	I
Arda	M***	I	M	I	M	T	M	N	M	T	M	I	M	T
Beste	T****	I	I	I	I	I	N	N	N	I	N	I	I	I
Burçak	M	I	M	I	M	T	M	I	M	T	M	I	M	I
Derya	N	I	T	I	N	N	N	I	I	T	N	I	I	I
Ebru	T	I	I	I	I	I	N	T	N	I	N	I	T	I
Erdi	I	I	I	T	T	T	N	I	T	I	I	I	I	I
Ferhat	M	I	M	I	M	T	M	N	M	I	M	T	M	I
Figen	T	I	I	I	I	T	N	I	T	I	N	I	I	I
Gözde	T	I	T	I	N	T	N	I	T	I	N	I	I	I
Gaye	I	I	N	I	I	I	N	I	T	I	N	I	T	I
Gökçe	I	I	T	I	N	T	N	I	N	I	N	I	T	I
Haydar	N	I	I	I	T	T	N	T	I	I	N	I	I	I

Table 24 (continued)

	NOS Aspects													
	Tentativeness		**Empirical-based**		**Observation & Inference**		**Theory & Law**		**Theory-Laden**		**Sociocultural-embedded**		**Creativity & Imagination**	
Participants	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Hale	T	T	N	N	I	N	N	I	I	I	I	T	I	I
Hülya	T	I	I	I	N	I	N	I	I	I	I	T	I	I
Haki	T	I	T	I	I	I	N	N	N	I	I	I	T	I
İzzet	I	I	I	I	I	I	N	I	N	T	I	T	I	I
Kader	I	I	N	N	I	I	I	I	I	I	I	I	T	I
Melek	N	I	T	T	N	I	N	I	I	I	N	I	I	I
Meral	N	I	N	I	I	I	N	I	N	I	I	I	T	I
Mehtap	I	I	N	I	T	I	N	I	N	I	N	I	T	I
Nilay	I	I	I	I	I	I	N	I	I	I	N	T	I	I
Nurdan	T	I	T	I	T	I	N	I	I	I	N	I	T	I
Özgün	I	I	T	T	T	N	N	T	I	I	I	T	I	I
Oya	T	I	T	T	I	I	N	I	T	T	N	N	T	T
Özden	I	I	N	I	I	I	T	I	T	I	N	I	I	I
Serhat	M	I	M	T	M	I	M	M	M	I	M	N	M	I
Serap	T	I	N	I	T	I	N	I	N	I	T	I	T	I
Yasemin	T	I	N	I	N	T	N	I	I	I	N	I	T	I

*I refers to informed view, **T refers to transitional views, ***M refers to missing data, ****N refers to naive view

4.2. Development of Pre-service Chemistry Teachers' PCK for NOS

In the PCK literature it is strongly recommended that researchers must focus on the interaction among the components (Abell, 2008) in order to understand the quality of PCK. Since a teacher's PCK highly depends on the degree of integration and coherence among components (Park & Oliver, 2008a; Friedrichsen Abell, Pareja, Brown, Lankford, & Volkman, 2009) and the literature provides the evidence for uneven development of PCK components (Hanuscin et al., 2011, Magnusson et al., 1999), I will focus on (a) the degree of integration among PCK components, (b) the frequency and nature of connections, (c) connections evident in application versus evident in knowledge only, and finally (d) the power of connections among the participants in the same category.

4.2.1. The Degree of Integration

The analysis of 30 pre-service chemistry teachers' post-intervention PCK for NOS maps showed that all participants developed PCK for NOS in some extent and nevertheless the participants' PCK for NOS were different from each other in terms of both the degree of integration among the components and the degree to which these components and connections manifest themselves in their lesson plans and reflection papers. Table 25 shows how pre-service chemistry teachers are distributed among seven categories emerged as a result of constant-comparison analysis of PCK maps. Results related to participants in each group will be presented separately.

Table 25. Number of participants in each PCK category

	Degree of translation into lesson plan		
	Knowledge	Knowledge-Application	Application
Degree of integration			
Highly-integrated	2	2	10
Somewhat-integrated	4	3	6
Non-integrated	0	0	3

4.2.1.1. Highly-Integrated PCK for NOS

The participants in this groups are the pre-service chemistry teachers who have five and six connection and consistency in their PCK for NOS map (the maximum number of connection and consistency can be six since there are four conponents of PCK for NOS). These group will be elaborated considering the degree to which those pre-service chemistry teachers translated their PCK for NOS into their lesson plans. First of all, participants in application level (i.e., five or six of the lines in their map are bold indicating they all translated the components that they developed to their lesson plans) will be explained, then in knowledge-application level (i.e., their map include a mixture of bold and solid lines indicating that they translated some of the componentd they developed), and finally in knowledge level (i.e., their map include one bold line and the rest is solid indicating that they could not translate all of the components they developed but one).

One third of the participants were categorized as application level, integrated the four components of PCK that were emphasized in the course, as evident in their lesson plans. All of them were oriented to teach NOS and included NOS objectives in their lesson plans as well as chemistry related ones. Also, their orientations to integrate NOS into their teachings were obvious in their reflection papers as they answered the question related to the purpose of their chemistry teaching. One of the pre-service chemistry teachers stated that "The purpose of chemistry education is to reach scientific literacy by helping students to understand and gain science process skills, nature of science as well as chemistry concepts.” Moreover, the NOS related objectives were evident in her lesson plan (e.g., students will be able to explain what theory is, what law is, the difference between theory and law). All participants in this group provided evidence for consistency of their KoL, KoA, and KoIS with their NOS teaching orientation in their lesson plans. They all planned their lesson considering students’ difficulties and misconceptions about NOS, used various types of explicit-reflective approaches as the instructional strategy, and assessed students’ understanding of NOS at the beginning, throughout, and/ or at the end of the lesson. For instance, one of the student teachers, Gozde, planned her lesson to teach Avogadro’s number and she asked her students to design an investigation for measuring the mass of one NaCl crystal where students only used observations. Her goal was to overcome students' belief in the myth that "Experiments are the principal routes to scientific knowledge (McComas, 1998)." After groups completed and presented their findings together with their investigation process, Gozde conducted an explicit-reflective debriefing by asking the questions of

> ...How did you measure the mass of one NaCl crystal? Did you conduct any experiment or did you just make observations? Is it possible to produce scientific knowledge without doing an experiment in science? Can you give examples of scientific knowledge where scientists rely on observations and inferences?...

To assess whether students changed their NOS conceptions, Gozde chose to have her students watch a video including different areas of science of which some of them use observation and experiment while other just can use observations. After students watched the video, she asked students to differentiate these areas and give examples from the video together with their reasoning.

In addition to consistencies evident in highly-integrated group's participants, six of the participants' KoL, KoA and KoIS informed each other in different ways. Five of them had connections among their KoL, KoIS, and KoA and four of them used their KoA to reveal students misconceptions on related NOS aspect they wanted to teach and then considered students' misconceptions when designing instruction. That is, their KoA consecutively informed their KoL and KoIS. They used concept maps, true-false test items, and questions to reveal students' misconceptions and then preferred instructional strategies and discussion questions to eliminate those misconceptions. For instance, Nilay administered 10 questions in true-false format as a pre-assessment and three of the questions were directly related to NOS; "Definitions about the phases of matter is absolute, Scientists produces unchangeable knowledge since they do numerous test, Scientists claim that previous knowledge in the discipline is wrong since they do not like each other." She stated that "The purpose of administering this test is to elicit students' misconception and design instruction considering students' misconception." Moreover, she conducted explicit-reflective discussion based on expected students' answers;

> **Nilay (N):** Scientists thought and searched for the nature and states of matter throughout the history. If you consider this process for producing scientific

knowledge, what are the things that stood out to you? Is there only one and only scientists studied on nature of matter?

Expected Student Answer (ESA): Lots of scientists worked on the same topic.

N: What else? Did any of them use the already existing knowledge in the discipline? or Did scientists start to work over?

ESA: Scientists used the previous knowledge available in the discipline produced by other scientists.

N: Were the knowledge accepted as absolute or did they change over time?

ESA: There was a change in scientific knowledge produced throughout history.

Also, Nilay explained the plasma state of matter and she stated that by this way she exemplified the tentativeness of scientific knowledge.

Five of the participants in highly integrated group were different than the ones mentioned above in that their KoL and KoIS informed their KoA. These participants specifically designed their lessons for eliminating students' misconceptions in related NOS aspect and they used specific assessment strategies to identify whether students still had these misconceptions at the end of the instruction which is an indication that their KoL informed their KoA. For instance, Hale formed three groups in class, then provided one area for each about the usage of radioactivity where instances of science and technology together and asked students to discuss whether which parts of these areas exemplifies science or technology. These areas were;

...The first one: Usage of radioactive elements for activating an automatic valve system that distributes petroleum to different tanks. The second one: Usage of radioactive elements (e.g., Co 60, Iodine 131) in the treatment of cancer and thyroid defect. The third one: Usage of radioactive elements in measuring the thickness of a material...

Hale at the end of the lesson asked her students give examples for both science and technology and had other students to express their ideas about the relevancy of examples. One pre-service chemistry teacher, Oya, differed from the others who had same number of integration in that she asked her students to design a poster where students were expected to present their investigation together with their understanding about NOS at the end of the lesson. In that lesson, Oya used explicit-reflective inquiry method to teach rate of reactions and several NOS aspects which is an indication that her KoIS informed her KoA.

So far, I have summarized the way pre-service chemistry teachers in highly-integrated group translated their PCK into their lesson plan, which are in application level. With regard to the participants in knowledge-application level, there was no clear pattern in terms of the components they developed and the degree to which they intagrated and translated those components. When it comes to participants in highly integrated group in knowledge level, I saw that both of them were aware that students' existing misconceptions are one of the difficulties they can encounter in their NOS teaching and they thought that first of all they should elicit students' misconceptions using various assessment techniques and then design instruction accordingly. Although they are aware the way they can integrate the components, they did not translate their knowledge into their lesson plan.

4.2.1.2. Somewhat-Integrated PCK for NOS

The participants in this groups are the pre-service chemistry teachers who have three and four connection and consistency in their PCK for NOS map (the maximum number of connection and consistency can be six since there are four conponents of PCK for NOS). These group will be elaborated considering the degree to which those pre-service chemistry teachers translated their PCK for NOS into their lesson plans. First of all, participants in application level (i.e., three or four of the lines in their map are bold indicating they all translated the components that they developed to their lesson plans) will be explained , then in knowledge-application level (i.e., their map include a mixture of bold and solid lines indicating that they translated some of the componentd they developed), and finally in knowledge level (i.e., their map include one bold line and the rest is solid indicating that they could not translate all of the components they developed but one).

One-fifth of the participants developed somewhat-integrated PCK for NOS as evident in their lesson plans (somewhat-integrated in application level, see Table 25).

Their post-intervention PCK for NOS maps showed that four of them were the same in terms of the nature of their PCK. Although they focused on anticipated student misconceptions about NOS (e.g., A general and universal scientific method exists and Experiments are the principal route to scientific knowledge, McComas, 1998) and used different types of instructional strategies (e.g., explicit-reflective-inquiry and explicit-reflective-case-based) to teach NOS, all four had KoL, KoIS, and KoA consistent with their orientation of teaching NOS. For instance, one of them, Figen, used guided-inquiry method in her lesson plan where students used a simulation of an electrochemical cell and were asked to write their observations and inferences throughout their investigation. After completion of presentation of investigations, she conducted an explicit reflective discussion on observation, inference, and the difference between them by asking the questions of “What are your observations?, How did you observe?, What are your inferences?, and What is the difference between observation and inference?” As an assessment opportunity, Figen preferred to use a project work, as she mentioned in her reflection paper, where students were required to design a cell and explain it using their knowledge about electrochemistry and NOS. In her reflection, she stated that “I learned how I can assess whether students learned nature of science or not. I learned different assessment methods such as concept maps, concept cartoons, project works, and question-answer method (informal way).” Another thing that is the same for four participants is the way they connected their KoL to their KoIS. In order to eliminate students’ misconceptions called as “Experiments are the principal route to scientific knowledge. (McComas, 1998)”, Hulya purposefully involved students in observing rate of dissolving (time passed for sugar to dissolve) of granule, powdered, and cube sugar in three beakers of waters at different temperatures (80°C, 25°C, and 0°C) and come up with an explanation. After groups shared their explanations, Hulya conducted an explicit-reflective discussion on the myth of experiments are the only route to scientific knowledge by asking the questions of

> ...What are their observations? How did they observe?, Which senses or what did they use? What are their inferences? How did they propose their explanations on what they observe? Is the observation only way to reach

valid and reliable claims in science? What are the other ways used in science? Is making experiment possible at all times in science?...

In other words, for all of the four participants in somewhat-integrated in application level group, their KoL informed their KoIS. Two participants in this group successfully translated their PCK for NOS into their lesson plans. They were similar in the sense that they were able to connect the components they developed. For instance, Ebru did not have KoA and therefore her map had integration among STO, KoL, and KoIS only, while Arda's PCK for NOS map showed connections among STO, KoIS, and KOA since he did not have well-developed KoL.

Three participants in this group were categorized as knowledge-application level. All the three pre-service chemistry teachers in this group provided consistency between their STO, KoA, and KoIS in their lesson plan whereas consistency between their STO and KoL stayed in knowledge level. Also, two participants' KoL informed their KoIS in knowledge level. Four pre-service chemistry teachers at knowledge level were similar in the sense that they could only align their KoIS with their STO in application. Also, all four developed KoL and KoA at knowledge level consistent with their STO. In addition to these consistencies, three of those participants' KoL informed their KoIS but they were not able to translate their understanding into lesson plan. For instance, Haydar emphasized the importance of considering misconceptions in his reflections as "When I saw the concept cartoons, I realized that there are some students who have various kinds of misconceptions about nature of science that I do not have. I thought that I should elicit students' misconceptions at first. If we ignore the existence of misconceptions, students will not learn targeted nature of science aspects and will continue to keep the misconceptions" but he did not consider to elicit students' misconceptions and did nothing in his lesson plan.

4.2.1.3. Non-Integrated PCK for NOS

The participants in this groups are the pre-service chemistry teachers who have two and one connection and consistency in their PCK for NOS map (the maximum number of connection and consistency can be six since there are four conponents of PCK for NOS). These group will be elaborated through the features of the participants in application level (i.e., two or one wof the lines in their map are bold indicating they all translated the components that they developed to their lesson plans) since there were no participants in knowledge-application and knowledge level. All three pre-service chemistry teachers in the non-integrated group were successful in aligning their KoIS with their STO. That is, they used explicit-reflective-inquiry and explicit-reflective-history of science approach to communicate various aspects of NOS (e.g., tentativeness, cumulative nature of science, creativity and imagination, and empirical-basis). It was not surprising that none of the three pre-service teachers had connections among KoL and other components since there was no evidence about their KoL in all data sources. Two of these participants had a consistency between their KoA and STO which is supported by their use of specific assessment strategies (e.g., having students interpret a case) to identify whether students understand the emphasized NOS aspect throughout the lesson. On the other hand, the other student teacher did not provide any evidence about his KoA and also, he did not consider assessing NOS in his lesson plans and reflections.

4.2.2. The Frequency and Nature of Connections

The connections and consistencies both evident in all 30 pre-service chemistry teachers' application (represented by bold lines) or knowledge level (represented by solid lines) were compiled into a comprehensive PCK for NOS map to provide a summary of the most and least frequent connections and to identify the outstanding features of integration of the PCK components (see Figure 15) within the group as a whole.

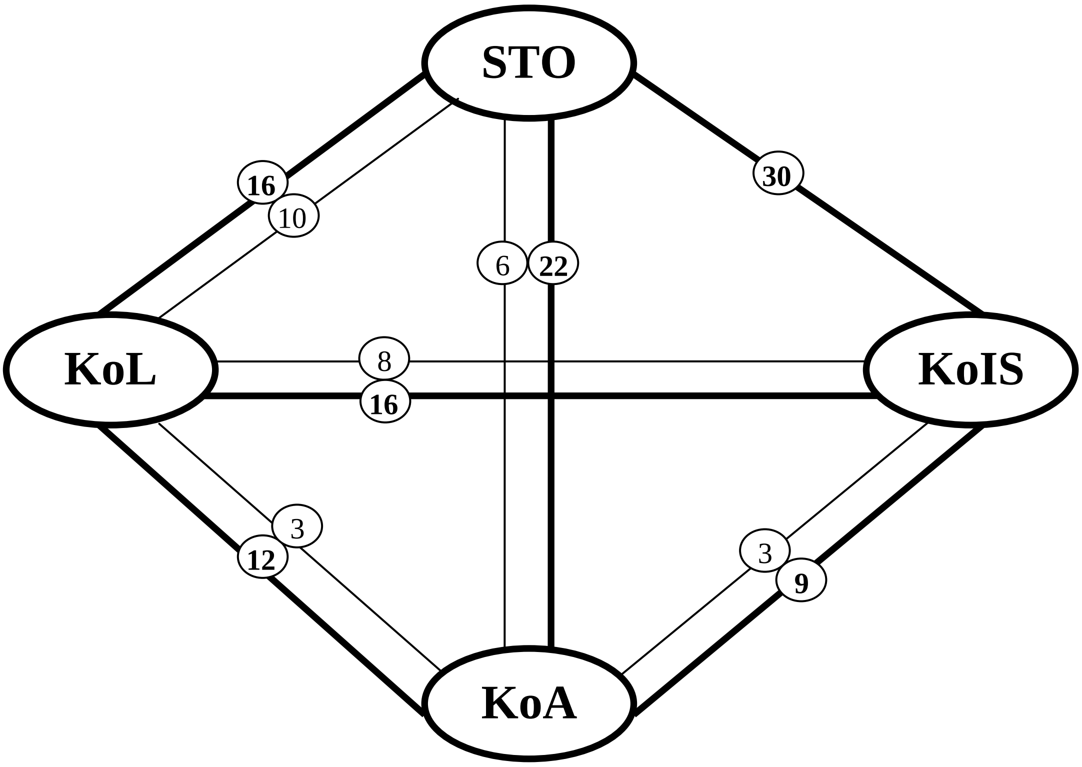

Figure 15. Comprehensive PCK for NOS map showing the frequency of connections among PCK components, evident in 30 participants' individual maps. Numbers in circles show the frequency of connection among two components.

While I was compiling individual maps into this map, I observed that integration of components was idiosyncratic. That is, the way and the degree they connected the components differed to a certain degree. This idiosyncrasy is evident from the distribution of participants among seven out of nine categories emerged during constant-comparative analysis of PCK for NOS maps (see Table 25). Moreover, even participants in the same category were different from each other in terms of the way they connected any two components of their PCK. For example, in some instances, pre-service teachers' KoA informed their KoIS and KoL and in others their KoL and KoIS informed teachers' KoA. Although there were different features for each map peculiar to oneself, there were common aspects shared by all maps. Until student teachers developed KoA, KoL, and KoIS either in knowledge or application level, they succeeded to align these components with their STO. That is, they were aware that students may have misconceptions and difficulties about NOS (e.g., confusing observation and inference; experiments are the principal routes to scientific knowledge), they used instructional strategies-various types of explicit-reflective approach to communicate aspects and to overcome misconceptions; and finally they assessed students' understanding of NOS using several assessment techniques (e.g., concept maps, concept cartoons, true-false questions, and question-answer method). In addition to these consistencies, the connection between KoL and KoIS was one way. At all times as long as there was a connection between those two components, pre-service teachers' KoL informed their KoIS.

Another salient feature that draws attention in all participants' post-intervention PCK for NOS map was that STO and KoIS was central to the integration. That is, they were the most frequently connected ones compared to any two others. In addition, the connection between STO and KoIS was the only one that all participants could translate their knowledge into application. When I looked at how pre-service chemistry teachers were successful in aligning their instructional strategy (KoIS) with their orientation of teaching NOS (STO), all but three decided to use various types of explicit-reflective approach in their teaching. Inquiry was the most preferred instructional teaching strategy (16) and the order of the preferences for instructional strategy was as; inquiry together with HOS (5), HOS (3), case-based (2), and activity (1). Only three of the participants used implicit approach for teaching NOS and again inquiry was preferred by two of them against HOS used by one.

To delve into the complexities the nature of interaction among KoL, KoIS, and KoA, I did a close analysis on the way these components inform each other and I came up with a new map (see Figure 16) representing all the interactions among KoL, KoIS, and KoA in both application (represented by bold lines) and knowledge level (represented by solid lines).

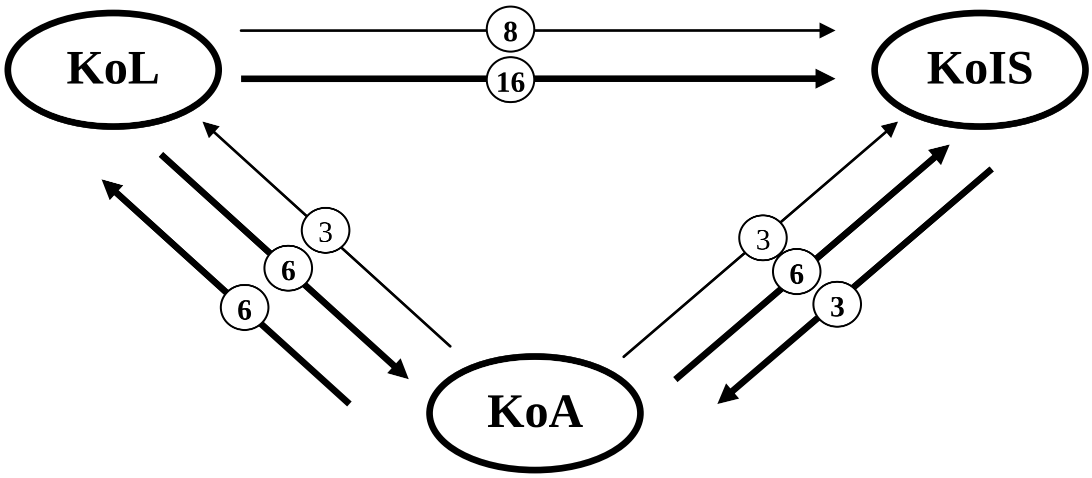

Figure 16. The map showing the nature of interaction among KoL, KoIS, and KoA

KoL was more often connected to KoIS than KoA and in addition, different than the other interactions among any two components, there was one way interaction between KoL and KoIS. That is, in all instances where teachers' KoL and KoIS are evident always participants' KoL informed their KoIS. Pre-service chemistry teachers who had this connection purposefully selected instructional strategies or asked appropriate questions in explicit-reflective discussions where they can dissatisfy or challenge students' existing misconceptions related to NOS. For instance, Yasemin designed her instruction to teach the difference between theory and law in the content of Graham Diffusion Law and carefully selected her explicit-reflective discussion questions. She assumed that students learned about Kinetic Molecular Theory in previous lesson and in that class Yasemin divided students into groups of four and asked to design an investigation to explore the factors affecting rate of diffusion of gases by providing the materials. After completion of the investigations students presented their investigation and what they found about diffusion of gases. Then, Yasemin conducted a whole class discussion on Graham Diffusion Law and also conducted an explicit-reflective class discussion on the nature of theory and law by asking the questions

> ...What does Graham diffusion tell about gases?, Does it describe a relationship or pattern?, What does Kinetic Molecular Theory tell us about

gases?, Does it describe a relationship or pattern too or does it explain the relationship or pattern described by laws?...

Although both of the interactions between KoL-KoA and KoA-KoIS are two directional, the number of connections between KoL-KoA (12) is more than the number of connections between KoA-KoIS (9). A closer look at the interaction between KoA and KoIS showed that teachers' KoA informed their KoIS twice as often as their KoIS informed their KoA. In the former, student teachers used assessment opportunities to reveal students' existing conceptions at the beginning and then design instruction accordingly or they used assessment tasks to understand whether students still hold misconceptions at the end of the lesson and then apply an instructional strategy to overcome the misconceptions. Among the participants who had KoL and KoA interaction, the number of cases where KoL informed KoA was equal to the number of cases where KoA informed KoL. Pre-service chemistry teachers who focused on eliminating a difficulty or misconception about NOS preferred to use specific assessment strategies to determine whether students were able to overcome these difficulties or misconceptions. For instance, Nurdan focused on differentiation between science and non-science in her teaching and as an assessment she asked students to interpret a cartoon (see Figure 17). For the participants of whom their KoA informed their KoL, they used assessment tasks to elicit students' misconceptions or difficulties about NOS. One of them explained her idea in her reflection paper as "Concept maps, concept cartoons, case, and diagnostic tree can be used to assess students' understanding of nature of science. I use these assessment methods to identify students' misconceptions about science and then design instruction considering misconceptions."

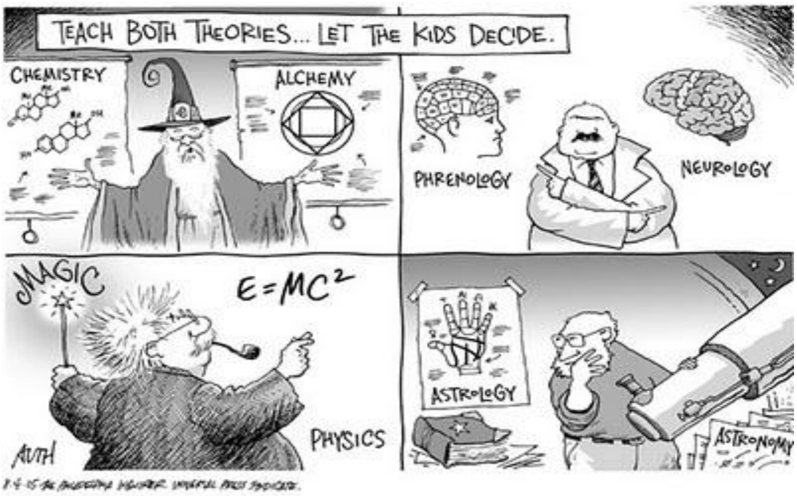

Figure 17. Cartoon used by Nurdan for assessment purposes

4.2.3. Connections Evident in Application versus Evident in Knowledge Alone

When I compared the number of participants who aligned their KoL, KoIS, and KoA with their STO in application versus knowledge (e.g., articulated in reflection papers but not lessons), I saw that translating their KoL into their lesson plans was the greatest area of difficulty (see Figure 15). Sixteen participants provided evidence about their KoL through focusing on helping students to eliminate at least their one of their misconceptions or difficulties related to NOS. On the other hand nine of 10 student teachers whose KoL was evident in their reflection papers had general ideas about their learners such as students may have misconceptions or prejudges about science. For instance, after KoL lesson Kader stated that

> Since I have had similar misconceptions before this lesson, I know that it is hard to eliminate students' misconceptions about nature of science. Therefore, I will be careful when teaching ideas about nature of science and try to eliminate misconceptions about NOS.

However, she did nothing to elicit and eliminate these misconceptions in her lesson plan. When it comes to KoA, participants were more successful in translating their KoA to their lesson (application level) than translating their KoL. Twenty two out of 30 participants assessed NOS in their lesson plans using various assessment techniques (see Table 26). On the other hand, although four of six participants who had consistency between KoA and STO in their knowledge level, as evident in their reflections, were aware of that they should assess students' understanding of NOS and the various ways they can use to assess (e.g., concept maps, concept cartoons, true-false items, and case), they did not consider assessing NOS in their lesson plans. Other two pre-service chemistry teachers in knowledge level rather developed awareness less than other four since the two just explained in their reflection papers that they should consider assessing NOS.

Table 26. Various assessment techniques used in lesson plans for assessing NOS

Preferred assessment techniques for NOS	Frequency
Concept map	6
Informal assessment	4
Giving examples	2
Poster	2
Video-case	2
Project work on the chemistry topic and emphasized NOS aspects	1
Cartoon	1
Concept cartoon	1
True-false test	1
Research on focused aspects	1
Diagnostic tree	1

Closer analysis of the ways KoL, KoIS, and KoA interact among themselves in application versus knowledge level revealed that although two way connections between KoL-KoA and KoA-KoIS were evident in participants' lesson plans, there were only one way interactions in knowledge level (see Figure 16). In addition, connecting KoL-KoA and KoA-KoIS in lesson plans was harder for participants than connecting KoL-KoIS. In some cases, participants used assessment opportunities to understand whether their students eliminate the misconceptions (that is their KoL informed their KoA) or they preferred an assessment strategy compatible with the instructional strategy (that is their KoIS informed their KoA) in their lesson plans. However, student teachers in knowledge level preferred to use assessment for the purpose of eliciting students' ideas about NOS and then design instruction accordingly. One of them explained in her reflection that "I realized that to elicit students' misconceptions and to identify whether students have adequate understanding about NOS, assessing nature of science is very important. We can revise or modify our nature of science teaching based on the assessment results." The connection between KoL and KoIS had the same nature both in application and knowledge level, that is always KoL informed KoIS.

4.2.4. The Power of Connections among the Participants in the Same Category

A closer look to the participants' PCK for NOS maps in the same category helped me to realize that although they had the same connections, they differed in terms of how powerfully connect the components of PCK. These differences emerged especially among the participants who can highly integrate their PCK in application and knowledge level. Therefore, in this part, I will focus on students in highly integrated group.

Five of the pre-service teachers in highly-integrated-application group used assessment opportunities to reveal students' misconceptions at some point throughout instruction (e.g., at the beginning and at the end) and then design instruction accordingly to remedy those misconceptions. But some of them used more effective ways for assessing and eliminating misconceptions. In her post interview, Derya stated that she preferred to have students to draw a concept map both in gases topic (e.g., ideal gas, real gas, Kinetic Molecular Theory, and Boyle-Mariotte Law) and NOS and to direct specific questions to reveal students' misconceptions. In her lesson plan, she conducted explicit-reflective discussion based on expected student answers with the aim of dissatisfy students existing ideas and the below is a section from her lesson plan

Derya (D): Why do we call Charles Law as law not as Charles theory?

ESA: Laws have more support/evidence than theories.

D: Is the difference related to amount of evidence? Laws have more support than theories?, Could somebody remind us kinetic molecular theory that we learned in previous class? Could somebody explain Charles Law? What is the difference between them? Is there a difference between what they tell us about the phenomena?

In another case, Gaye asked students to investigate Gilbert Newton Lewis before the class they teach about polarity in covalent bonds, had students share what they found and then conducted explicit-reflective discussion considering expected students' misconceptions. Moreover, she was aware one of the sources (daily life usage of the words) of the misconception about the hierarchical relationship between theory and law, explained it to students, and then gave several examples (e.g., evolution theory, gas laws, kinetic molecular theory) to explain the nature of theories and laws and the difference between them. A part from Gaye's lesson plan is as follows;

> **Gaye (G):** Why do we call it as Lewis theory although it shed light modern chemistry? and Can there be a Lewis Law?
>
> **ESAs:** (1) Since the truth of Lewis theory is not proved, it is not called as law, (2) Since it is not directly observable, it stayed as theory. For instance, evolution is a theory and it is not observable too, and (3) The Lewis theory is not accepted by all scientific community and therefore stayed as theory not become a law.
>
> **G:** There is difference between the way we used the word theory in our daily life and the way it is used in science (scientific theory) and the continued that If the truth of theories was not proved or theories were not accepted by most of the scientific community, we would not teach and learn in our chemistry or science classes.

Burcak who focused on the nature and role of observation and inference in science preferred to use two gestalt pictures in order to overcome the misconception of "Scientific knowledge is based on the only careful observations. There is no room for inference." She asked students to observe and then made a whole class discussion. Different from Burcak, Gaye, and Derya two of the pre-service teachers who used assessment at first to reveal misconceptions and then for informing instruction preferred to use lecturing when they identified students still had misconceptions at the end of the class. As an assessment one of them used question-answer method and the other one asked her students to draw a concept map. Similarly, two student teachers in highly-integrated-knowledge level group differed in terms of the proposed assessment and instructional method to overcome students' misconceptions. While one of them just mentioned about her ideas about assessment and misconceptions in general sense saying that “I realized that to elicit students’ misconceptions and to identify whether students have adequate understanding about NOS, assessing nature of science is very important. We can revise or modify our nature of science teaching based on the assessment results.” The other one explained that videos, concept maps, and concept cartoons could be used to elicit students’ ideas and then strategies that create dissatisfaction with students’ existing ideas should be used.

4.3. Relationship between Pre-service Chemistry Teachers’ NOS Understanding and their PCK for NOS

Lack of NOS understanding has been pointed out as one of the factors that impede translation of teachers’ NOS understanding into classroom teaching (Abd-El-Khalick et al., 1998; Akerson et al., 2009; Lederman, 1999; Lederman et al., 2001; Ochanji, 2003; Schwartz & Lederman, 2002). Therefore, in this part the relationship, if existed, between the participants’ PCK for NOS and NOS understanding was elaborated. As explained in the development of pre-service chemistry teachers’ PCK for NOS part, 30 participants were different from each other in terms of both the degree to which they integrated the PCK for NOS components they developed and the degree to which those components and connections/consistencies among components manifested themselves in their lesson plans and reflection papers. Although there was nine-dimensional matrix (see Table 25), the participants were distributed among seven categories. There were no participants in non-integrated in knowledge-application level and non-integrated in knowledge level.

In order to understand whether there is clear relationship between the participants’ NOS understanding and their PCK for NOS, various comparisons were made by using the data of participants in the same group (e.g., highly-integrated in application level) and different group (e.g., highly-integrated in application level vs. highly-integrated in knowledge level and highly-integrated vs. non-integrated). First of all, a comparison was made among the participants with highly-integrated, somewhat-integrated, and non-integrated group. Those participants were compared in terms of number of informed, transitional, and naïve views as indicated in their VNOS-C. There was no clear pattern or relationship between those two (e.g., the more number of informed view a participant have about NOS aspects the more integrated PCK for NOS s/he has). Secondly, the participants in the same group (e.g., somewhat-integrated) but from different levels (e.g., application, knowledge-application, and knowledge) were compared and no clear pattern or relationship was found either. Finally, participants' profiles were examined to see the aspects they addressed in their lesson plans and to identify what kind of views they had about the aspects they addressed (see Table 26). It was revealed that most of the participants attempted to teach NOS aspects on which s/he had informed view. Only four participants (Burçak, Oya, Figen, and Erdi) included the NOS aspects of which they had transitional views. When those participants' and profiles were examined again, it was seen that they relied on their informed views during their explicit-reflective discussions. More interestingly, two participants (Ferhat and Kader) designed their instruction to teach the aspects that they have naïve views about them. As a result of their limited NOS understandings, those two participants were categorized in somewhat-integrated in knowledge level and non-integrated in application level.

As a final point, some participants addressed some myths about NOS (e.g., models are not copies of the reality) and some NOS aspects that were not addressed in VNOS-C but addressed in our NOS instruction (e.g., scientific knowledge is cumulative). For instance, Nurdan taught the difference between science and non-science. When her VNOS-C was analyzed, it was observed that she had informed views all NOS aspects in VNOS-C. Also, her lesson plan provided evidence about her adequate NOS understanding through the explicit-reflective discussions she conducted. Gökçe addressed cumulative nature of scientific knowledge and Ayşe attempted to eliminate the myth of "a universal and step-by-step scientific method exists". Similarly both have informed views on almost all of the NOS aspects (five out of seven, see Table 26) and transitional views on the others. Interestingly, Hale included the difference between science and technology and Özgün addressed the nature of scientific models in their lesson although they had some naïve views on some NOS aspects (two out of seven, see Table 27). Again, their lesson plans were reviewed whether there was any evidence about translation of their naïve views to their teaching. No evidence was found in that respect.

Table 27. Each participants' PCK for NOS and NOS Aspects addressed in his/her lesson plan

Participants	Tentativeness	Empirical-based	Observation & Inference	Theory & Law	Theory-Laden	Sociocultural-embedded	Creativity & Imagination	PCK for NOS
Burçak	I	I	T*	I	T	I	I	HI-A[1]
Derya	I*	I	N	I*	T	I	I	HI-A
Gözde	I	I*	T	I	I	I	I	HI-A
Gaye	I	I	I	I*	I	I	I	HI-A
Mehtap	I*	I	I	I*	I*	I	I*	HI-A
Nilay	I*	I	I	I	I*	T	I*	HI-A
Nurdan	I	I	I	I	I	I	I	HI-A
Oya	I	T	I	I	T*	N	T*	HI-A
Hale	T	N	N	I	I	T	I	HI-A
Melek	I	T	I*	I	I*	I	I*	HI-A
Yasemin	I	I	T	I*	I	I	I	HI-KA[2]
Beste	I	I*	I	N	I	I	I	HI-KA
Ahmet	I	I*	I	I	T	I*	I*	HI-K[3]
Gökçe	I	I	T	I	I	I	I	HI-K
Ayse	I	T	I	T	I	I	I	SI-A[4]
Arda	I*	I*	T	N	T	I	T	SI-A
Ebru	I	I	I	T	I	I	I*	SI-A
Figen	I	I	T*	I	I	I	I	SI-A

Table 27 (continued)

Participants	Tentativeness	Empirical-based	Observation & Inference	Theory & Law	Theory-Laden	Sociocultural-embedded	Creativity & Imagination	PCK for NOS
Hülya	I	I*	I	I	I	T	I	SI-A
Özden	I	I*	I	I	I	I	I	SI-A
İzzet	I	I*	I	I	T*	T	I	SI-KA[5]
Meral	I	I*	I	I	I*	I	I*	SI-KA
Serhat	I*	T	I	M	I*	N	I*	SI-KA
Erdi	I	T	T*	I	I	I	I	SI-K[6]
Haydar	I*	I	T	T	I*	I	I	SI-K
Kader	I	N*	I*	I	I	I	I*	SI-K
Özgün	I	T	N	T	I	T	I	SI-K
Ferhat	I*	I	T	N*	I*	T	I	NI-A[7]
Haki	I	I	I	N	I	I	I*	NI-A
Serap	I	I*	I	I	I	I	I	NI-A

* indicates the NOS aspect addressed in lesson plan, 1 represents Highly-Integrated in Application level, 2 represents Highly-Integrated in Knowledge- Application level, 3 represents Highly-Integrated in Knowledge level, 4 represents Somewhat-Integrated in Application level, 5 represents Somewhat-Integrated in Knowledge- Application level, 6 represents Somewhat-Integrated in Knowledge level, and 7 represents Non-Integrated in Application level

4.4. Summary of Results

In this study, both how pre-service chemistry teachers' changed their NOS understanding and they developed PCK for NOS were explored after participating to the course including learning NOS and how to teach NOS. The main findings of the study are as below;

- Before NOS instruction, majority of the pre-service chemistry teachers had naïve and transitional views about various NOS aspects. Most of the pre-service chemistry teachers used to think that
  - Some scientific knowledge is absolute such as laws (53.3%)
  - Experiments are the principal routes to scientific knowledge (60%)
  - Science based on confirmation and proof (73.4%)
  - Law is an unchanged reality. On the other hand, theory is a knowledge which is not accepted by all scientists and can change with new information (83.3%)
  - Science is objective and there is place for subjectivity (53.3%)
  - Science is universal and not affected from social and cultural factors (56.6%)
  - Creativity and imagination is used in planning and design of an investigation. Data collection and interpretation must be based on evidence (43.3%)
  - Technology is the application of science (82%).
- After the pre-service chemistry teachers learned NOS through explicit-reflective NOS instruction, which spanned one and half semester, most of them had informed views on numerous NOS aspects. However, few of them still indicated naïve views about some NOS aspects; namely, scientific knowledge is empirical-based (6.7%) and social-cultural embedded (6.7%) as well as the roles of both observation and inference (10%) and theory and law (13.3%) and the difference between those.
- Examination of pre-service chemistry teachers' first lesson plans, which were prepared before PCK for NOS instruction, indicated that only two of them integrated NOS into their teaching using implicit approach.

- Although there were some similarities among 30 pre-service chemistry teachers' post intervention PCK map, the way and the extent to which participants connected the components differed to a certain degree. Those pre-service chemistry teachers were distributed among seven out of nine categories (the degree of integration vs. the degree of translation, also see Table 25). Also, participants in the same category were different from each other in terms of the way they connected any two components of their PCK.
- Development of pre-service chemistry teachers' PCK was uneven, that is changes in one PCK component (e.g., knowledge of instructional strategies) may not be accompanied by the changes in another component (e.g., knowledge of assessment).
- In terms of the frequency and nature of connections, it was revealed that KoIS and STO were central to the integration and were the only ones that all participants could translate their knowledge into their lesson plans.
- Through the participation to PCK for NOS instruction, all but three pre-service chemistry teachers developed KoIS effective for teaching NOS more successfully than any other components.
- With regard to the way KoL, KoIS, and KoA inform each other, there was only one way interaction between KoL and KoIS, in contrast, interactions between KoL-KoA and KoIS-KoA were two directional. In all cases where participants connect their KoL with KoIS, always their KoL informed their KoIS. Also, number of participants who could use their KoL to design instruction was higher than the ones who can connect KoL-KoA and KoA-KoIS.
- When the comparisons were made between connections evident in application versus evident in knowledge indicated that pre-service chemistry teachers were more successful in translating their KoA and KoIS into their lesson plans than they do KoL.
- There was no clear relationship between pre-service chemistry teachers' NOS understanding and their PCK for NOS (e.g., the more number of informed views on NOS aspects, the more integrated PCK for NOS s/he has). However, most of the participants preferred to teach the NOS aspect/s that

they had informed view/s about. Only four participants included the NOS aspects of which they had transitional views but they relied on their informed views during their explicit-reflective discussions. More interestingly, two participants designed their instruction to teach the aspects that they have naïve views about them and expectedly those two were categorized in somewhat-integrated in knowledge level and non-integrated in application level. Also, some participants addressed some myths about NOS (e.g., models are not copies of the reality) and some NOS aspects that were not addressed in VNOS-C but addressed in our NOS instruction (e.g., scientific knowledge is cumulative).

CHAPTER V

DISCUSSION, CONCLUSION, and IMPLICATIONS

In this chapter, first of all, the results, which are the change in pre-service chemistry teachers' NOS views, PCK for NOS, and the relationship between NOS understanding and PCK for NOS, were discussed. Then, conclusions were made based on the results derived from the study. Finally, implications for pre- and in-service education, curriculum developers, and textbook writers and recommendations for science education research were presented.

5.1. Discussions

In this part, results of the study were compared and contrasted with the other studies on NOS, PCK, and PCK for NOS. Since there were three main results of this study (i.e., the change in NOS understanding, development of PCK for NOS, and the relationship between teachers' NOS understanding and their PCK for NOS), each result was discussed under different headings as discussion of the results for the change in NOS understanding, discussion of the results for PCK for NOS, and finally discussion of the results for NOS understanding and PCK for NOS.

5.1.1. Discussion of the Results for the Change in NOS Understanding

In this part, I will discuss findings with regard to how and to what degree the-pre-service chemistry teachers' NOS understanding changed considering their NOS views before and after NOS instruction, and then how NOS instruction influenced that change.

First, vast majority of the pre-service chemistry teachers had naïve and transitional views about various NOS aspects (e.g., scientific knowledge is absolute, theories change while law do not, scientists are objective, technology is the application of science, and science is based on confirmation), which is consistent with the literature indicating that both pre and in-service teachers lack of informed NOS understanding (Abd-El-Khalick & BouJaoude, 1997; Akerson et al., 2008; Aslan, 2009; Ayvaci & Er Nas, 2010; Brown et al., 2006; Chen, 2001; Doğan, 2005; Doğan et al., 2011; Erdoğan, 2004; Gürses et al.,, 2005; Haidar, 1999; Lederman, 1992; Liang et al. 2008; Liu & Lederman, 2007; Murcia & Schibeci, 1999; Şahin et al., 2006; Tairab, 2001; Thye & Kwen, 2003; Yalvaç et al., 2007). the majority of the pre-service teachers had naive view on the theory and law aspect. This aspect was followed by sociocultural-embedded and theory-laden NOS aspects. These findings were similar with the others (Aslan, 2009; Chen, 2001; Doğan, 2005; Haidar, 1999; Liang et al., 2008; Tairab, 2001; Yalvaç et al., 2007) revealing that both pre and in-service teachers experienced the most difficulty in understanding theory and law, sociocultural-embedded, and theory-laden NOS aspects. Creative and imaginative aspect was the one about which pre-service chemistry teachers did not have naïve views instead they had transitional and informed views about that aspect, which is compatible with the literature (Akerson, Abd-El-Khalick, & Lederman 2000; Ayvacı & Er Nas, 2010).

Second, analysis of pre-service chemistry teachers' views after NOS instruction indicated that most of the participants tackled their naïve and transitional views on most of the NOS aspects (e.g., tentativeness, theory-laden, creativity and imagination, and difference between science and technology) whereas few of them still had naïve views about several NOS aspects, namely, scientific knowledge is empirical-based (6.7%) and social-cultural embedded (6.7%) as well as the roles of both observation and inference (10%) and theory and law (13.3%) and the difference between those. These findings are consistent with the findings of studies investigating the effect of various teaching approaches on NOS understanding (Abd-El-Khalick & Akerson, 2004; Abd-El-Khalick, Bell, & Lederman, 1998; Akerson et al., 2000; Lin & Chen, 2002). Those findings were evidence for the fact that pre-service chemistry teachers' naïve views about those aspects were resistant to change even after explicit-reflective NOS instruction spanned one and half semester. Also, this is compatible with the research on misconceptions, pointing out that they are resistant to change (Posner, Strike, Hewson, & Gertzog, 1982). Pre-service chemistry teachers built their NOS understanding as a result of long-lasting primary, secondary, and higher education communicating implicit NOS aspects through various ways (e.g., science teachers' language and textbooks). Throughout their education, science textbooks, teachers, classroom instruction and laboratory experiences have been perceived to influence the formation of students' NOS understanding (McComas, Clough, & Almazroa, 2000). For instance, until recently, the hierarchical relationship between theory and law has been presented in science textbook while explaining the scientific method (Abd-El-Khalick, Waters, & Le, 2008; İrez, 2009). The pre-service chemistry teachers themselves pointed out various factors accounted for the naïve NOS views they had before NOS instruction. These factors are as not being taught NOS in schools, inability to disprove existing theories and laws, textbooks, TV shows, traditional science teaching, internet, and journals. They advocated that especially textbooks, TV shows, internet, and journals communicate implicit messages about theories and laws through the language they used. For instance, theory is used for the ideas that are not tested and law is used for the things that do not change. Therefore, science teachers should be alert about the implicit NOS messages received by their students via the language and textbooks they used during their instruction. Additionally, teachers should be engaged in various opportunities in various contexts for more informed NOS understanding as emphasized by Akerson, Morrison, and McDuffie (2006).

Third, although pre-service chemistry teachers had naïve and transitional views on numerous NOS aspects, there was a substantial increase in the percentage of participants with informed views on the majority of the NOS aspects as a result of explicit-reflective NOS instruction. This is consistent with the findings of Abd-El-Khalick & Lederman, 2000a, 2000b; Akerson et al., 2000; Abd-El-Khalick & Akerson, 2004; Ayvacı, 2007; Bell, Matkins, & Gansneder, 2011; Lin & Chen, 2002; McDonald, 2010. More specifically, various settings, namely, argumentation inquiry, and HOS served as contexts throughout explicit-reflective NOS instruction in this study. These contexts created a collaborative and social environment where pre-service chemistry teachers explained their ideas about NOS, compared their NOS understandings with the ones addressed in the activities, realized the myths they had about NOS and critically discussed on them, and finally made inferences about NOS considering all those experiences. The effectiveness of those environments, where learners are provided authentic science experiences, on NOS understanding also was supported by others for HOS (Abd-El-Khalick & Lederman, 2000b), argumentation (McDonald, 2010; Ogunniyi, 2006), and inquiry (Schwartz & Crawford, (2004; Yacoubian & BouJaoude, 2010). Another salient feature of NOS instruction in this study is its' long-lasting nature. The NOS instruction spanned one and half semester and moreover, the pre-service chemistry teachers engaged in PCK for NOS activities where they both learned and taught about NOS. This long-lasting nature helped the participants to retain and translate their NOS understandings into other settings more easily than the others learned NOS in shorter period. Although, the instruction in this study was not enough for stimulating the change for all participants from naïve views to the informed ones, this kind of change might be realized by engaging students in explicit-reflective NOS activities in various settings and encouraging them to transfer those understandings into other settings (e.g., decision-making on socioscientific issues) (Akerson et al., 2006; Lynne Eastwood et al., 2012).

5.1.2. Discussion of the Results for PCK for NOS

In this part, I will discuss findings related to pre-service chemistry teachers' PCK for NOS considering applicability of Magnusson et al.'s PCK model as a lens for research on teaching NOS; nature of PCK for NOS developed throughout instruction - the nature of PCK for NOS itself (e.g., general, discipline-specific, and topic specific), similarity and difference among participants' PCK, the way and the degree to which components and connections manifested themselves in lesson plans and reflection papers; the frequency and nature of connections in terms of centrality of components and connections; and PCK components of which pre-service teachers have difficulty in translating these components into their lesson plans.

First of all, this research provided evidence for applicability of Magnusson et al.' (1999) PCK model in characterizing and evaluating the quality of teachers' PCK for NOS, which is consistent with the literature (Faikhamta, 2012; Hanuscin & Hian, 2009; Hanuscin et al., 2011). Another important finding about the nature of PCK for

NOS was its idiosyncratic nature, which has been empirically supported by other scholars (Loughran, Mulhall, & Berry, 2008; Park & Chen, 2011; Van Driel et al., 1998) for other topics (e.g., chemical equilibrium, photosynthesis, and heredity). Although there were some similarities among 30 participants' post intervention PCK map revealed as a result of constant comparative analysis, the way and the extent to which participants connected the components differed to a certain degree. This idiosyncrasy was evident from the distribution of participants among seven out of nine categories (the degree on integration vs. the degree of translation, also see Table 3) and even participants in the same category were different from each other in terms of the way they connected any two components of their PCK. For instance, the highly integrated participants differed in terms of how powerfully they connect the components of PCK. While some of the participants used more specific assessment techniques to reveal misconceptions and then preferred to use instructional strategies that dissatisfy students with their existing ideas, others used question-answer method to understand whether students still had misconceptions at some point in the lesson and then lectured about emphasized NOS aspects.

When I examined students' first lesson plans prepared after learning NOS part I saw that only two of the participants integrated NOS into their teaching using implicit approach. They both did not state their NOS related objectives explicitly, and in their post interviews they stated that they assumed students could learn NOS through experiencing the science itself. This finding supported the view that even when teachers have informed understandings of NOS consistent with reforms, they generally do not explicitly teach NOS (Schwartz & Lederman, 2002). Analysis of various data sources (lesson plans 2, reflection papers, and interviews) used throughout and after PCK for NOS instruction indicated that all participants developed PCK for NOS in some extent. However, the participants' PCK for NOS were different from each other in terms of both the degree of integration among the components and the degree to which these components and connections manifest themselves in their lesson plans and reflection papers. While some of the participants in highly integrated group developed all components of PCK and translate these components and connections among them into their lesson plans some others in somewhat integrated group were not able to connect all components or to develop some components (e.g., KoL, KoA). Similarly, participants in non-integrated group did not develop KoL and/or KoA. Students in knowledge level for each integration category had similar type of connections among the components but they could not translate those into their lesson plans. These findings are compatible with prior researches (Hanuscin & Hian, 2009; Hanuscin et al., 2011; Magnusson et al., 1999) suggesting that the development of teachers' PCK may be uneven, that is changes in knowledge of one component (e.g., knowledge of instructional strategies) may not be accompanied by changes in other components (e.g., knowledge of assessment).

I also explored the frequency and nature of connections to shed light on the degree to which the instruction was successful in improving students' PCK for NOS. When individual maps were compiled into a group map, I saw that KoIS and STO were central to the integration and was the only ones that all participants could translate their knowledge into their lesson plans. This integration showed that PCK for NOS instruction tackled an important challenge namely helping teachers in internalizing NOS as an important learning outcome and achievable by students (Abd-El-Khalick et al., 1998; Schwartz & Lederman, 2002). Also this instruction fulfilled the lack of research on providing guidance for how to develop teachers' valuing of NOS (Lederman, 2007), which is compatible with the finding that a PCK-based NOS course contributed to the change in in-service science teachers' orientations to teach science (Faikhamta, 2012). Through the participation to PCK for NOS instruction, all but three pre-service chemistry teachers developed KoIS effective for teaching NOS more successfully than any other components. This finding aligns with the research providing evidence for teachers' development of instructional strategies is more than development of assessment (Abd-El-Khalick et al., 1998; Bell et al., 2000; Hanuscin & Hian, 2009). In contrast to prior studies (Bell et al., 2000; Hanuscin & Hian, 2009) most of the pre-service chemistry teachers in this study (22 out of 30) specifically assessed students' understanding of NOS as evident in their lesson plans. Some attribute teachers' inability to assess NOS to their lack of knowledge of strategies for assessing students' NOS understanding (Hanuscin & Hian, 2009) while others hold the discrepancy between practice and belief in the importance of teaching NOS responsible for teachers' not assessing NOS (Abd-El-Khalick et al., 1998). In both circumstances, the PCK for NOS instruction helped student teachers to align their belief with their practice and to increase their knowledge of assessment in terms of both what and how to assess. Another interesting finding is related to the way KoL, KoIS, and KoA inform each other. While there was only one way interaction between KoL and KoIS, in contrast, interactions between KoL-KoA and KoIS-KoA were two directional. In all cases where participants connect their KoL with KoIS, always their KoL informed their KoIS and they purposefully used several instructional strategies to overcome students' misconceptions about NOS. Also, number of participants who could use their KoL to design instruction was higher than the ones who can connect KoL-KoA and KoA-KoIS. Although there is no universally accepted elements for PCK, this provides empirical evidence for the agreed upon elements on PCK components as KoL and KoIS (Park & Chen, 2011; Park & Oliver, 2008a; Shulman, 1986)

Comparisons of connections evident in application versus evident in knowledge only helped me to understand the PCK components of which pre-service teachers had difficulty in translating these components into their lesson plans. Participants were more successful in translating their KoA and KoIS into their lesson plans than they do KoL. Several studies provided consistent findings about teachers KoL. In a study by De Jong and Van Driel (2001) they reported that even in-service teachers did not have concerns for students' learning. Also, several studies indicated that pre-service teachers do not consider students' ideas in their practice adequately (Park & Chen, 2011; Tabachnick & Zeichner, 1999). Since participants of this study did not have the chance to implement their lesson plans in real classrooms, they were not able to translate their KoL into their lesson plans which supports the explanation of KoL improves with teaching experience (Abell, 2007). The other reason for pre-service teachers' having difficulty in considering students' ideas was attributed to teachers' limited KoA (Hanuscin & Hian, 2009). This explains another important finding; participants had the most difficulty in using assessment revealing students' ideas and designing or revising the instruction accordingly. Another reason for why pre-service chemistry teachers had difficulty in translating their KoL into their lesson plan may be related to the nature of KoL class during PCK for NOS instruction. Although students' difficulties and misconceptions about NOS were adressed in that class, several participants stated that they eliminated their own miconceptions about

NOS after that class rather than they learned how to eliminate students' misconceptions in their future classes. Also, there was only one directional connection between KoL-KoA and KoIS-KoA in knowledge level although two directional connections were evident in lesson plans. Knowledge level pre-service teachers did not consider the ways where their KoL and KoIS might inform their KoA. Since these pre-service teachers could not translate their knowledge into their lesson plan, they might not have seen or discover possible alternative ways where they could connect KoL-KoA and KoIS-KoA.

The discussion on nature of PCK for NOS helped me to answer the sub-problem of “Which PCK model (general PCK, discipline-specific PCK, or topic specific PCK) best explains the nature of PCK for NOS?” Although Magnusson et al.’s (1999) PCK model helped me examine the interplay among PCK components, the use of this model does not imply that I am taking any stance towards to the nature of PCK for NOS (e.g., discipline-specific, topic specific, and general). In addition to idiosyncratic nature another important aspect that needs consideration about PCK for NOS is its’ nature. I proposed several assertions related to categorization of PCK for NOS based on the literature as general PCK (Veal & MaKinster, 1999) and topic specific PCK (Hanuscin & Hian, 2009; Hanuscin et al., 2011; Lederman, 1998). When one teaches NOS as its’ own content using content generic activities, topic-specific nature may fully explain the way teachers’ translation of their NOS understanding into teaching. But, what happens when one teaches NOS using content embedded activities? For instance, one chemistry teacher may have PCK for both atomic theories and acid-base theories and both of the topics may provide opportunities teaching the same aspects such as nature of theories. This instance was evident in our participants’ lesson plans. Although Ferhat prepared his lesson on teaching atomic theories and Haydar designed a lesson on acid-base theories, and they have different PCK for these different chemistry topics both of them used explicit-reflective approach to teach nature of theories. At this point, argument proposed by Davis and colleagues (2008) resolved the issue. They advocated that “…[w]hile PCK is typically conceptualized as topic-specific, teachers also need discipline-specific knowledge about how a discipline works” (2008, p. 6). Moreover, Davis and Krajcik (2005) defined PCK for disciplinary practices as “teachers must know how to help students understand the authentic activities of a discipline, the ways knowledge is developed in a particular field, and the beliefs that represent a sophisticated understanding of how the field works (p. 5). Davis et al. (2008) deepened their argument by discussing on PCK for scientific modeling including "…knowledge of instructional strategies that can promote students' engagement in modeling practices and learning of metamodeling knowledge…[as well as] teacher's knowledge of their students' ideas and the challenges students face, again associated with modeling practices and metamodeling knowledge" (p. 6). Discipline specific perspective helps to explain teachers' NOS teaching practices in appropriate contents. Reflecting on nature of PCK for NOS helped me to fill the gap in understanding different types of PCK (e.g., general, discipline-specific, and topic specific) and deepened my knowledge on science teacher knowledge.

Finally, since pre-service teachers have relatively undeveloped PCK (Van Driel et al., 1998). However, bearing in mind that pre-service teachers will enact these knowledge when they become practicing teachers, one can think pre-service teachers' PCK as their PCK readiness (Davis, 2003; Smithey, 2003) or PCK pre-packaging and pursue some research on their PCK (Abd-El-Khalick et al., 1998; Bell et al., 2000). More evidence is needed how these pre-service chemistry teachers unpack their PCK for NOS and enact in their classroom practices.

5.1.3. Discussion of the Results for the Relationship between NOS Understanding and PCK for NOS

There have been several efforts for understanding how teachers' NOS understanding and their classroom practices are related. Those efforts revealed that no clear-cut relationship between the two and moreover, inadequate NOS understanding has been pointed out as one of the factors that impede both pre and in-service teachers' translation of their NOS understanding into effective NOS teaching practices (Abd-El-Khalick et al., 1998; Akerson & Abd-El-Khalick, 2003; 1998; Akerson et al., 2009; Bell et al., 2000; Lederman, 1999; Lederman et al., 2001; Ochanji, 2003; Schwartz & Lederman, 2002). More importantly, there is a need for research on how SMK, NOS, and pedagogy contribute to the formation of PCK for

NOS (Lederman, 2007; Schwartz & Lederman, 2002). Although, the need has been well documented, the relationship between NOS understanding and their PCK for NOS was not articulated by the ones using an explicit PCK for NOS framework (e.g., Hanuscin et al., 2011; Lederman et al., 2001). For instance, Hanusin et al. (2011) investigated three elementary teachers' PCK for NOS, who both had informed NOS understanding and were successful in improving their students' NOS understanding. Their findings indicated that three teachers had robust knowledge of instructional strategies indicating itself in several ways (e.g., drawing analogies and using children's literature) and lacked of knowledge of assessment. However, how teachers with different PCK for NOS were the same or different was not an explicit concern.

One of the most important findings of this study was the absence of clear-cut relationship between the pre-service chemistry teachers' NOS understandings and their PCK for NOS. In other words, no pattern was detected with regard to NOS understanding among the participants in the same group (e.g., highly-integrated in application level vs. highly integrated in knowledge level) and the participants in different groups (e.g., highly-integrated vs. somewhat-integrated). However, a closer look revealed that majority of the participants provided evidence for his/her PCK for NOS in the NOS aspects of which they had informed views. This finding was expectable knowing that one cannot teach what s/he does not understand (Shulman, 1986). Interestingly, two of the pre-service chemistry teachers' PCK for NOS indicated itself in the aspects that they had naïve views and consequently one of them was categorized in somewhat-integrated in knowledge level and the other was in non-integrated application level. This finding is consistent with the view that SMK, which refers to NOS understanding in this study, is a pre-requisite for a rich PCK (Aydın, 2012; Shulman, 1986).

5.2. Conclusion

In this study, how pre-service chemistry teachers' changed their NOS understanding, how they developed PCK for NOS, and how their NOS understanding and PCK for NOS related were explored after participating to the course including learning NOS and how to teach NOS.Khishfe and Lederman's (2002) framework, assuming a continual change in students' understanding about NOS (as naïve, transitional, and informed) was used for the analysis of NOS understandings. Based on the analysis of the participants' VNOS-C and associated interviews, the following conclusions were made:

- As long as pre-service chemistry teachers do not receive explicit NOS instruction, they have naïve and transitional views about various NOS aspects, namely, scientific knowledge is tentative, empirical-based, theory-laden, and sociocultural-embedded as well as the role of creativity and imagination in science, and the roles of both observation and inference and theory and law and the difference between those.

- Long-lasting explicit-reflective NOS instruction is effective in terms of helping pre-service chemistry teachers to have more informed views on numerous NOS aspects, namely, scientific knowledge is tentative, theory-laden, and the role of creativity and imagination in science.

- Pre-service chemistry teachers' NOS understandings about several NOS aspects (e.g., scientific knowledge is empirical-based and social-cultural embedded as well as the roles of both observation and inference and theory and law and the difference between those) are resistant to change.

For the PCK for NOS part, Magnusson et al.'s (1999) PCK model formed the conceptual basis and the sophistication of participants' PCK was analyzed considering the interaction among components since teachers' PCK depends on the degree of integration and coherence among its' components (Friedrichsen et al., 2009; Magnusson et al., 1999; Park & Oliver, 2008a). Based on the analysis of lesson plans and reflection papers, the following conclusions were made:

- Even when teachers have informed understandings of NOS consistent with reforms, they generally do not explicitly teach NOS.

- PCK for NOS instruction, where PCK components (e.g., science teaching orientation and knowledge of assessment) are addressed explicitly, is effective in helping teachers to internalize NOS as an important learning outcome and achievable by students.

- Magnusson et al.'s (1999) PCK model is applicable for research on in characterizing and evaluating the quality of teachers' PCK for NOS.

- PCK for NOS has an idiosyncratic nature, which implies that every teacher is different from each other in terms of the PCK for NOS components s/he develops, the degree to which s/he develops those components, and the way s/he integrates components of PCK for NOS.

- Development of PCK for NOS is uneven, that is changes in one PCK component (e.g., knowledge of instructional strategies) may not be accompanied by the changes in another component (e.g., knowledge of assessment).

- PCK for NOS instruction, where PCK components (e.g., science teaching orientation and knowledge of assessment) are addressed explicitly, is effective in stimulating the development of teachers' knowledge of instructional strategy and knowledge of assessment for NOS.

- Enhancing teachers' knowledge of learner of NOS is difficult even after that PCK for NOS component is addressed explicitly in PCK for NOS instruction.

For investigating how pre-service chemistry teachers NOS understandings and their PCK for NOS was related, various comparisons were made among the participants with the same (e.g., highly-integrated in application level) and different PCK for NOS (e.g., highly-integrated in application level vs. highly-integrated in knowledge level and highly-integrated vs. non-integrated). Based on these comparisons, I can conclude that

- There is no clear-cut relationship between teachers' NOS understanding and their PCK for NOS.

- Teachers attempt to teach the NOS aspect/s that they have informed view/s about or they rely on their informed views during their explicit-reflective discussions.

5.3. Implications of the Study

This study has several implications for pre-service and in-service teacher education, textbook writers, and curriculum developers, based on the results obtained and discussions made.

This study showed that both pre- and in-service teachers' views are not compatible with the contemporary conceptions of and therefore teachers have difficulty with teaching an appropriate view to students. Accordingly, both pre and in-service teachers need courses or workshops enhance their NOS understanding. Those workshops or courses should provide teachers with opportunities of which they engage in explicit-reflective discussions on NOS. They should include several important features for effective NOS teaching and learning as evidenced in the NOS instruction developed and implemented in this study;

- Reflection: After engaging in various research experiences, students take a step back from the role of "researcher" and take the role of "reflector" in order to understand how their experiences relate to NOS.
- Context: "Reflection" requires a context. Inquiry, argumentation, scientific process skills, HOS, and hands-on activities may serve as important contexts in which students reflect on their experiences.
- Students do not do "NOS". Instead they engage in experiences which provide opportunities to students to reflect on their experiences from the perspective of what science is, what scientific knowledge is, and how science works. Thus, students make informed inferences about NOS.
- Long-lasting: NOS teaching experiences should last at least one semester or more.

Also, the PCK for NOS instruction followed NOS instruction required pre-service chemistry teachers to integrate NOS into their chemistry teaching. This translation helped pre-service chemistry teachers to re-reflect their own NOS understanding and to re-construct more informed understandings of NOS aspects they are going to teach. Therefore, the courses or workshops aiming to develop pre-service or in-service teachers' NOS understanding should be long lasting, provide opportunities where teachers reflect on NOS aspects explicitly in various contexts, and include the various teaching (e.g., co-teaching NOS to peers and being required to make NOS explicit of their instruction through objectives, activities, and assessment) opportunities.

The organization of teaching opportunities has crucial importance since there are factors directly influencing teachers' translation of their NOS understandings into their teaching NOS, namely PCK for NOS. For stimulating the development of PCK for NOS, first of all, both pre- and in-service teachers should be provided with the opportunities where they study NOS from teaching perspective. This can be realized by enacting an explicit PCK framework (e.g., Magnusson et al., 1999) on a course where NOS is taught. Moreover, individual PCK components should be revisited in a way where teachers are able to see how those components connect with each other. Teachers, especially pre-service, may have difficulty in seeing the relevance of PCK for NOS instruction to their teaching. Also, they may think from the perspective of learner not the teacher. Therefore, both pre-service teachers and in-service should be engaged in explicit-reflective discussions on their STO, KoL, KoIS, KoA, and KoC and the way they connect these knowledge bases and they should reflect on their experiences as teachers.

Second, there are several issues that impede teachers' translation of their NOS understanding into their teaching and could be resolved by both textbook writers and curriculum developers. These issues are pressure to cover content, concern about not being able to spend enough time for teaching basic knowledge of science because of the time allocated for NOS teaching, concerns about students' abilities and motivation for learning NOS, and lack of resources and experience for teaching and/or assessing understandings of the NOS. If curriculum developers include NOS objectives as well as content related objectives (e.g., physics, chemistry, and biology) and more importantly both curriculum developers and textbook writers provide activities for assessing and teaching NOS, teachers easily may tackle the aforementioned challenges.

5.4. Recommendations for Science Education Research

This study has some implications for science education research, which would contribute to research on PCK and PCK for NOS and science teacher education. These are;

1. PCK is an elusive construct because of its tacit nature and this leaves researchers with a challenging task; making tacit nature of PCK explicit. In depth analysis of explicit PCK method is very valuable in resolving that issue through creating PCK profiles, including evidences of PCK components and interplay among them, and finally visualizing the PCK with maps. Considering the recent existence of in-depth analysis of explicit PCK method, there needs to be more research on to what extend this model captures the complex nature of PCK.

2. PCK for NOS is an area of research that needs further investigation. With regard to stimulating the development of PCK for NOS, how the use of Content Representation (CoRes) and Professional and Pedagogical experience Repertoire (PaP-eRs), about NOS developed by experienced teachers, contributes to PCK for NOS should be investigated.

3. Considering the discussion on nature of PCK for NOS, much research is required on different types of PCK in order to shed light on nature of PCK for NOS. Which type of PCK can fully capture the way teachers enact their PCK for NOS? General, topic-specific, or discipline specific? Is topic specific PCK (e.g., PCK for acid-base theories) a pre-requisite for development PCK for NOS or vice versa? Or should topic specific PCK and PCK for NOS be developed in a parallel way at the same time?

4. Also, it would be beneficial to explore how teachers with different level of NOS understanding enact their PCK for NOS in their classroom to understand the relationship between NOS understanding and PCK for NOS.

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APPENDIX A

FIVE YEAR CHEMISTRY TEACHER EDUCATION PROGRAM

BİRİNCİ YIL*

I. Yarıyıl

KODU	DERSİN ADI	T	U	K
KİM101G	Atatürk İlkeleri ve İnkılap Tarihi-I	2	0	**2**
KİM103G	Analiz I	4	0	**4**
KİM105A	Temel Kimya I	4	2	**5**
KİM107G	Genel Biyoloji	3	0	**3**
KİM109M	Eğitim Bilimine Giriş	3	0	**3**
KİM111A	Fizik I	4	0	**4**
YAD-ALM-101GK	Yabancı Dil-I (Almanca)	3	0	**3**
YAD-FRA-101GK	Yabancı Dil-I (Fransızca)	3	0	**3**
YAD-ING-101GK	Yabancı Dil-I (İngilizce)	3	0	**3**
	Kredi			**23**

II. Yarıyıl

KODU	DERSİN ADI	T	U	K
KİM102G	Atatürk İlkeleri ve İnkılap Tarihi II	2	0	**2**
KİM104G	Analiz II	4	0	**4**
KİM106A	Temel Kimya II	4	2	**5**
KİM108A	Temel Kimya Laboratuvarı	0	2	**1**
KİM110A	Fizik Laboratuvarı	0	2	**1**
KİM112A	Fizik II (Dalgalar, Optik ve Modern Fizik)	4	0	**4**
KİM114M	Gelişim Psikolojisi	3	0	**3**
YAD-ALM-102GK	Yabancı Dil-II (Almanca)	3	0	**3**
YAD-FRA-102GK	Yabancı Dil-II (Fransızca)	3	0	**3**
YAD-ING-102GK	Yabancı Dil-II (İngilizce)	3	0	**3**
	Kredi			**23**

İKİNCİ YIL*

III. Yarıyıl

KODU	DERSİN ADI	T	U	K
KİM201G	Türk Dili-I	2	0	**2**
KİM203G	Bilgisayar-I	2	2	**3**
KİM205M	Türk Eğitim Sistemi ve Okul Yönetimi	2	0	**2**
KİM207A	Analitik Kimya-I	4	2	**5**
KİM209A	Analitik Kimya Laboratuvarı-I	0	6	**2**
YAD-ALM-201GK	Yabancı Dil-III (Almanca)	3	0	**3**
YAD-FRA-201GK	Yabancı Dil-III (Fransızca)	3	0	**3**
YAD-ING-201GK	Yabancı Dil-III (İngilizce)	3	0	**3**
	Kredi			**21**

IV. Yarıyıl

KODU	DERSİN ADI	T	U	K
KİM202G	Türk Dili-II	2	0	**2**
KİM204G	Bilgisayar II	2	2	**3**
KİM206M	Sınıf Yönetimi	2	0	**2**
KİM208A	Analitik Kimya-II	4	2	**5**
KİM210A	Analitik Kimya Laboratuvarı-II	0	6	**2**
KİM212A	Anorganik Kimya-II	4	0	**4**
KİM214A	Anorganik Kimya Laboratuvarı	0	2	**1**
YAD-ALM-202GK	Yabancı Dil-IV (Almanca)	3	0	**3**
YAD-FRA-202GK	Yabancı Dil-IV (Fransızca)	3	0	**3**
YAD-ING-202GK	Yabancı Dil-IV (İngilizce)	3	0	**3**
	Kredi			**22**

ÜÇÜNCÜ YIL*

V. Yarıyıl

KODU	DERSİN ADI	T	U	K
KİM303M	Rehberlik	3	0	**3**
KİM305A	Organik Kimya-I	4	2	**5**
KİM307A	Organik Kimya Laboratuvarı-I	0	6	**2**
KİM309A	Enstrümental Analiz	4	0	**4**
KİM311G	Seçmeli (Bilim Felsefesi)	2	0	**2**
KİM313G	Seçmeli (İnsan Hakları ve Demokrasi)	2	0	**2**
KİM315G	Seçmeli (Günümüz Dünya Sorunları)	2	0	**2**
KİM317G	Seçmeli (Güzel Konuşma ve Sunum Becerileri)	2	0	**2**
KİM319G	Seçmeli (Temel Hukuk)	2	0	**2**
		Kredi		**16**

VI. Yarıyıl

KODU	DERSİN ADI	T	U	K
KİM304M	Öğrenme Öğretme Kuram ve Yaklaşımları	3	0	**3**
KİM306A	Organik Kimya-II	4	2	**5**
KİM308A	Organik Kimya Laboratuvarı-II	0	4	**1**
KİM310A	Ayırma Metotları	2	0	**2**
KİM312A	Kimyacılar İçin Matematik	2	0	**2**
KİM314A	Seçmeli (Metaller Kimyası)	2	0	**2**
KİM316A	Seçmeli (Çevre Kimyası)	2	0	**2**
KİM318A	Seçmeli (Potansiyometrik Titrasyonlar)	2	0	**2**
KİM320A	Seçmeli (Nükleer Kimya)	2	0	**2**
		Kredi		**15**

DÖRDÜNCÜ YIL*

VII. Yarıyıl

KODU	DERSİN ADI	T	U	K
KİM401M	Özel Öğretim Yöntemleri-I	2	2	**3**
KİM403M	Program Geliştirme ve Öğretim	3	0	**3**
KİM405A	Fizikokimya-I	4	2	**5**
KİM407A	Ortaöğretim Kimya Den. Lab.	0	4	**1**
KİM409G	Bilim Tarihi	2	0	**2**
KİM411A	Seçmeli (Ametaller Kimyası)	2	0	**2**
KİM413A	Seçmeli (Elektroanalitik Kimya)	2	0	**2**
KİM415A	Seçmeli (Karbonil Bileşikler Kim.)	2	0	**2**
KİM417G	Seçmeli (Türkiye Beşeri ve Ekonomik Coğrafyası)	2	0	**2**
KİM419G	Seçmeli (Yeni ve Yakın Çağ Tarihi)	2	0	**2**
KİM421G	Seçmeli (Astronomi)	2	0	**2**
KİM423G	Seçmeli (Topluma Hizmet Uygulamaları)	1	2	**2**
KİM425G	Seçmeli (Genel Ekonomi Bilgisi)	2	0	**2**
KİM427G	Seçmeli	2	0	**2**
	Kredi			**18**

VIII. Yarıyıl

KODU	DERSİN ADI	T	U	K
KİM402M	Özel Öğretim Yöntemleri-II	2	2	**3**
KİM404M	Ölçme ve Değerlendirme	3	0	**3**
KİM406A	Fizikokimya-II	4	2	**5**
KİM408A	Fizikokimya Laboratuvarı	0	4	**1**
KİM410A	Biyokimya	4	0	**4**
KİM412M	Seçmeli (Bilim Teknoloji Toplum)	2	0	**2**
KİM414M	Seçmeli (Bilimin Doğası)	2	0	**2**
KİM416A	Seçmeli (Kuantum Kimyası)	2	0	**2**
KİM416M	Seçmeli (Kimya Eğitiminde Bilgisayar Uygulamaları)	2	0	**2**
KİM418A	Seçmeli (Polarografi)	2	0	**2**
KİM420A	Seçmeli (Atomik Spektroskopi)	2	0	**2**
KİM422A	Seçmeli (Korozyon)	2	0	**2**
KİM424A	Seçmeli (Polimer Kimyası)	2	0	**2**
	Kredi		**20**	

BEŞİNCİ YIL**

IX. Yarıyıl

KODU	DERSİN ADI	T	U	K
ÖFD501	Öğretim Teknolojileri ve Materyal Geliştirme	2	2	**3**
ÖFD503	Sınıf Yönetimi	2	2	**3**
ÖFD505	Özel Öğretim Yöntemleri II	2	2	**3**
ÖFD507	Okul Deneyimi II	1	4	**3**
ÖFD509	Seçmeli I (Kimya Eğitimi İle İlgili Araştırmalar I)	3	0	**3**
ÖFD511	Seçmeli I (Kimya Eğitiminde Temel Kavramlar I)	3	0	**3**
ÖFD513	Seçmeli I (Kimya Eğitiminde Kavram Yanlışlıkları I)	3	0	**3**
ÖFD515	Seçmeli I (Temel Kimya Kavramlarının Öğretilmesi I)	3	0	**3**
ÖFD517	Seçmeli I (Kimya Bilim Tarihi)	3	0	**3**
ÖFD519	Seçmeli I (Kimyasal Kavramların Öğretiminin Ölçülmesi)	3	0	**3**
	Kredi			**15**

X. Yarıyıl

KODU	DERSİN ADI	T	U	K
ÖFD502	Konu Alanı Ders Kitabı İncelemesi	2	2	**3**
ÖFD504	Rehberlik	3	0	**3**
ÖFD506	Öğretmenlik Uygulaması	2	6	**5**
ÖFD508	Seçmeli II (Kimya Eğitimi İle İlgili Araştırmalar II)	3	0	**3**
ÖFD510	Seçmeli II (Kimya Eğitiminde Temel Kavramlar II)	3	0	**3**
ÖFD512	Seçmeli II (Kimya Eğitiminde Kavram Yanlışlıkları II)	3	0	**3**
ÖFD514	Seçmeli II (Temel Kimya Kavramlarının Öğretilmesi II)	3	0	**3**
ÖFD516	Seçmeli II (Kimya Eğitimi Araştırmaları İçin İstatistiksel Yöntemler)	3	0	**3**
ÖFD518	Seçmeli II (Kimya Eğitiminde Bilgisayar Teknolojisinin Kullanımı)	3	0	**3**
	Kredi		**14**	

APPENDIX B

EXPLICIT-REFLECTIVE ACTIVITIES DURING NOS INSTRUCTION

ETKİNLİK-1
BİLİMİN DOĞASI ÖĞRETİMİNDE İLK ADIM:
YENİ TOPLUM ETKİNLİĞİ

Konu: Bilimin Doğası

Gereken Süre: 2 ders saati

Gerekçe:

Yapılan araştırmalar birçok insanın bilimi karmaşık ve erişilemez bir uğraş olarak gördüklerini ortaya koymuştur. Bilim ve bilim insanı ile ilgili olumsuz algılar öğrencilerin bilim hakkında düşünmekten ve konuşmaktan kaçınmasına ve bu nedenle en iyi şekilde tasarlanan bilimin doğası öğretim sürecinin bile etkisiz olmasına yol açabilmektedir. Bu durum göz önünde bulundurularak bilimin doğasının öğretimine yönelik ilk etkinlik katılımcılara bilimle ilgili olumsuz ön yargılarını hissettirmeden onların sosyal bir bağlamda bilimsel sorgulama sürecini yaşamaları amacıyla tasarlanmıştır. Bu etkinlikte sosyal bir bağlamın kullanılması katılımcıların alan bilgisi kullanmalarını gerektirmediği için farklı katılımcı profili çizen her türlü grup için bilimin doğası öğretimine yönelik ilk derste kullanılabilecek bir etkinliktir.

Neye İhtiyaç Var?

- Bu etkinlik için herhangi bir materyale ihtiyaç duyulmamaktadır.
- Katılımcıların not tutması amacıyla sadece kalem ve kağıt kullanımını gerektirmektedir.

Nasıl Yapılır?

Katılımcılara bilimin doğası hakkında konuşmaya başladıklarını “fark ettirmeden” onların sosyal bir bağlamda bilim ve bilimsel süreçle meşgul olmalarını sağlayacak Yeni Toplum etkinliği literatürden (Cavallo, 2008) uyarlanmıştır. Bu etkinlik kendine has kuralları olan, bu kurallara göre yaşayan ve hiç kimse tarafından bilinmeyen bir toplumun bilim insanları tarafından keşfedilmesi ve bilim insanlarının toplumun belli kurallara göre yaşadığından haberdar olmadan toplum hakkında bilgi elde etme sürecini içermektedir. Toplumun kuralları şu şekildedir:

- **Kural 1:** Toplum üyeleri sadece "evet" ve "hayır" kelimelerinden oluşan bir dili konuşmaktadırlar.
- **Kural 2:** Eğer bilim insanı toplum üyelerinden birine gülümseyerek soru sorarsa soru ne olursa olsun cevap daima "evet", gülümsemeden sorarsa cevap daima "hayır" olacaktır.
- **Kural 3:** Toplum üyeleri ancak aynı cinsiyetteki (veya aynı özellikteki) bilim insanı tarafından yöneltilen sorulara cevap verecektir.

İlk olarak, katılımcılar arasından dört kişi bilim insanı takımını oluşturmak üzere seçilerek sınıfın dışında bekletilir. Bilim insanı takımı seçilirken toplumun kurallarının göz önünde bulundurularak takımın farklı cinsiyette (veya farklı özellikte), gülümseyen ve asık suratlı bilim insanlarından oluşmasına dikkat edilir. Bazı uygulamalarda sınıftaki erkek katılımcıların az sayıda olması ve kadın katılımcı sayısının çok fazla olması kadın bilim insanlarının veri toplayabilmelerini sınırlayacağı için cinsiyet faktörünü içeren kural gözlük takıp-takmama veya herhangi bir fiziksel özelliğe göre (ten rengi, saç rengi ve saçın düz-dalgalı olması gibi) tekrar uyarlanabilir. Sınıfta kalan katılımcılara keşfedilecek olan yeni toplumun üyeleri oldukları söylenir ve bu toplumun kendine ait kuralları onlara açıklanır.

Bilim insanı takımı sınıfa çağrılmadan önce toplum üyelerini oluşturacak olan katılımcılara bilim insanı takımının kuralları keşfetme süreci boyunca gözlemlemeleri ve gözlemlerini not almaları söylenir. Dışarıda beklemekte olan bilim insanı takımına yeni bir toplum keşfettikleri ve bu toplumun kurallarından bahsetmeden sadece toplum hakkında mümkün olduğu kadar çok şey bulmaları gerektiği açıklanır. Bilim insanı takımı dışarıda beklerken bu keşif sürecinde ilk olarak ne yapacaklarını tasarlarlar ve kendilerinden içeri girdikleri zaman süreç boyunca not tutmaları istenir. Kurallar toplum üyelerini oluşturacak katılımcılar tarafından iyice anlaşıldıktan sonra bilim insanı takımı sınıfa çağırılır ve takım toplum üzerinde araştırma yapmaya başlar. Bilim insanı takımı toplumun kurallarını keşfettikten sonra etkinlik uygulayıcıları tarafından toplum üyelerinin ve bilim insanlarının aldıkları notlar yardımı ile “bilim nedir?”, “bilim nasıl çalışır?” ve bilim insanları nasıl çalışırlar?” gibi soruların cevaplarını bulmak amacıyla tartışma yürütülür.

Kaynak:

Cavallo, A. (2008). Experiencing the Nature of Science: An Interactive, Beginning-of-Semester activity. *Journal of College in Science Teaching,* May/june, 12-15.

Çalışma Kağıtları:

Bilimsel Sorgulama Süreci ile Tanışma: Yeni Toplum Etkinliği

1. Bu dersten öğrendiklerim

Bilim:____

Bilim insanı:____

Bilimsel bilgi:____

Bilimsel metot:____

2. Bu etkinlik bundan sonra yapacağım derslerde kullanacağım/kullanmayacağım bir etkinliktir. Çünkü:

Adınız-Soyadınız:...

Alanınız:...

TOPLUM ÜYELERİNİN ARAŞTIRMA SÜRECİNDEKİ GÖZLEM NOTLARI

Adınız-Soyadınız:...

Alanınız:...

Bilim insanları nasıl veri topladılar?

Bilim insanlarının topladıkları veriler ve ulaştıkları çıkarımlar:

Bilim insanları bir araya gelip görüşlerini paylaştılar mı? Nasıl görüş birliğine ulaştılar?

Araştırmanın sonucu:

Bilim insanının dikkatinizi çeken özellikleri:

BİLİM İNSANININ NOT DEFTERİ

Adınız-Soyadınız:..
Alanınız:...

Toplum ile ilgili ne tür bilgiler toplamayı planlıyorsunuz?

Nasıl veri topluyorsunuz?

Topladığınız veriler:

Bir araya gelip görüşlerinizi paylaştınız mı? Nasıl görüş birliğine vardınız?

Araştırmanızın sonucu:

ETKİNLİK-2

GİZEMLİ TAŞLAR: LİTOLOJİ

Konu: Kayaçların Sınıflandırması

Gereken Süre: 2 ders saati

Gerekçe:

Öğretmen ve öğrencilerin bilimin değişebilir, deneye dayalı, kısmen hayal gücü ve yaratıcılık ürünü olduğunu ve sosyal ve kültürel etmenlerden etkilendiğini sadece bilimin içeriğini ve süreçlerini öğrenerek anlayabileceklerine inanmak güçtür. Bu nedenle öğrencilere bilimsel girişimin doğasını anlamaları konusunda açık bir şekilde bir rehberlik yapmaları için fen eğitimcileri ve öğretmenlerinin büyük bir çaba göstermesi gerektiğine inanıyoruz. Bilimin doğası ile ilgili ders kitapları tarafından doğru olmayan bir şekilde aktarılan kavramlardan biri doğal dünya hakkında sorulan her soruya bilim insanlarının eninde sonunda "doğru ve eksiksiz" bir cevap bulacaklarıdır. Öğrencilerin kitaplarda bölüm sonundaki alıştırmalara doğru bir cevap vermelerini, çoktan seçmeli testlerde doğru şıkkı işaretlemelerini veya "cook-book (bak-yap)" şeklinde yürütülen laboratuar derslerinde doğru sonuca varmalarını gerektiren bu tip etkinlikler "doğru ve eksiksiz bir cevap bulma" kavramının pekişmesine yol açmaktadır.

Bu kavram ve deneyimler bilimsel bilginin oluşma şekliyle uyum içerisinde değildir. Bilim insanlarının araştırdıkları sorulara tek bir cevap bulmaları çok nadir görülen bir durumdur. Bunun sebebi bilimsel bilginin, en azından kısmen, deneysel delillerle desteklenmesine rağmen, çoğunlukla insan çıkarımının, hayal gücünün ve yaratıcılığının sonucu ortaya çıkmasıdır. Bundan dolayı bilimsel bilgi hiçbir zaman kesin ve mutlak değildir. Teori ve kanunları da içeren bilimsel bilgi değişebilir. Bu etkinlik, öğrencilerin "doğru ve eksiksiz bir cevap bulma" kavramının ortadan kaldırılmasına yardımcı olmaktadır.

Neye İhtiyaç Var?

- Çeşitli renk ve şekilde kayaç örnekleri
- Öğrenci çalışma kağıdı

Nasıl Yapılır?

Katılımcılar bu etkinlik için dört ya da beş kişiden oluşan bilim insanı gruplarına ayrılırlar. İlk aşamada taşların kimyasal ya da bilimsel olarak bilinen fiziksel özellikleri verilmeden gruplardan kendi içlerinde gözlem yoluyla sınıflandırma yapmaları beklenir. İkinci aşamada taşların fiziksel özellikleri verilir. Bu aşamada daha önce yapılan sınıflandırmadan farklı olabilecek bir sınıflandırma biçimi düşünülürse, bir önceki sınıflandırma değiştirilebilir. Üçüncü aşamada taşların kimyasal formülleri verilir. Bu aşamada da 2. Aşamada olduğu gibi yapılan sınıflandırmanın değişmesi gerektiği düşünülürse geçerli yeni bir sınıflandırma yapabilir.

Grupların yaptıkları sınıflandırmalar etkinlik sonunda bir tabloya yan yana yazılır. Tabloda her bir grubun her bir aşamada yaptığı sınıflandırma tüm katılımcılar tarafından görülür.

Çalışmanın süresi ve niteliği değişiklik gösterebilir. Örneğin ilk aşamada katılımcılara gözlem yaparken kullanmaları için büyüteç verilebilir, ikinci aşamada kütle, yoğunluk ve hacim ölçmeleri için gerekli malzemeler verilebilir, üçüncü aşamada kimyasal özellikleri tespit edebilmeleri için asit, baz gibi kimyasallar sağlanabilir.

ETKİNLİK-3

AY'IN EVRELERİ – AY VE GÜNEŞ TUTULMASI

Konu: Ay'ın Evreleri – Ay ve Güneş tutulması

Gereken Süre: 3 ders saati

Gerekçe:

Öğretmenler konularını öğretirlerken modellerden oldukça fazla yararlanırlar. Modeller öğrencilerin olayları zihinlerinde canlandırmasını kolaylaştırır. Bununla beraber öğretmenlerin modelleri kullanırlarken dikkat etmeleri gereken çok önemli noktalar vardır. Örneğin modellerin gerçeğin kopyası olmadığını, sadece bir gösterim olduğunu vurgulamaları gerekir. Modellerin deney ve bazen de sadece gözlem yapma yoluyla oluşabileceğini dolayısıyla bilimsel bir bilgi oluşurken deneyin şart olmadığını vurgulayabilir. Aynı zamanda aynı konu ile ilgili farklı bilim insanlarının farklı modellerinin olabileceğini ve bunun bilimin doğasının boyutlarından biri olduğunu anlatması gerekir.

Neye İhtiyaç Var?

- Şeffaf disk
- Pinpon topu
- Oyun hamuru
- Çubuk
- El feneri
- Sakızlı yapışkan

Nasıl Yapılır?

Etkinlik 1: Ay'ın Evreleri

Grup çalışmasının etkin bir şekilde kullanılacağı bu etkinlikte katılımcılardan 3-4 kişilik gruplar oluşturmaları istenir. Etkinlik, Ay'ın evreleri ile ilgili öğrencilerde çok sık rastlanan bir yanlış kavramanın kavram karikatürleri şeklinde sunulması ile başlatılır. Burada katılımcılar kavram karikatürlerinin öğrencilerin sahip olabileceği mitleri ortaya çıkarabilmede ve argüman oluşturma becerilerini geliştirmede uygun bir yöntem olduğunu fark ederler. Daha sonra kendi argümanlarını modeller ile desteklemeleri için onlara verilen malzemeleri (çöp şiş, Pinpon topu, Sakızlı yapışkan, el feneri) kullanarak Ay'ın evrelerinin nasıl oluştuğunu modellemeleri istenir. Burada katılımcılardan pinpon topunu sakızlı yapışkan yardımı ile çöp şişe tutturarak Ayı, kendi başlarını dünya, burunlarını da dünya üzerinde yaşadıkları yer olarak modellemeleri beklenir. Etkinlik sonunda gruplardan modellerini sunmaları ve bu modellerle kendi argümanlarını desteklemeleri ya da hatalar varsa diğer gruplardan müdahale etmeleri ve çürütmeleri istenir.

Etkinlik 2:Ay ve Güneş tutulması neden gerçekleşir?

Dikkat Çekme**:** Katılımcıların dikkatini derse çekmek amacı ile katılımcılara aşağıda yer alan sorular yöneltilir ve bu derste hep birlikte bu soruların cevaplarının bulunacağı söylenir. "22 Temmuz 2009'da gerçekleşen yüzyılın en uzun süren güneş tutulmasını milyonlarca kişi ilgiyle izledi. Güney Asya'dan izlenebilen tutulmanın hiçbir evresi, Türkiye'den görülemedi."

- ✓ 22 Temmuz'da gerçekleşen güneş tutulmasının Türkiye'den görülmemesinin sebebi nedir?
- ✓ Güneş ve Ay tutulması neden gerçekleşir?

Araştırma**:** Sınıf 6-7 kişiden oluşan gruplara ayrılır. Her gruba pinpon topu, el feneri, çubuk ve oyun hamuru verilerek güneş tutulmasının nasıl gerçekleştiğini gösteren bir model oluşturmaları istenir. Gruplar modellerini oluşturduktan sonra her grup oluşturduğu model ve güneş tutulmasının nasıl gerçekleştiği ile ilgili sınıfa bir sunum yapar. Katılımcılara model oluşturma esnasında aşağıdaki sorular sorularak rehberlik yapılır.

- ✓ Dünya, Güneş ve Ay birbirinden hangi açılardan farklıdır? (Büyüklük, ısı ve ışık yayma vb.)
- ✓ Dünya, Güneş ve Ay'ın uzayda konumları nasıldır?
- ✓ Dünya, Güneş ve Ay'ın konumu sabit midir? Değilse hareketleri nasıldır?

Güneş tutulmasını temel olarak anladıktan sonra katılımcılara "Neden her ay tutulma gerçekleşmez?" sorusu yöneltilir ve tekrar gruplar halinde bu soruyu açıklayan bir model oluşturmaları istenir. Gruplara şeffaf disk, oyun hamuru, çubuk ve el feneri verilir. Gruplar modellerini oluşturduktan sonra her grup oluşturduğu model ve güneş tutulmasının nasıl gerçekleştiği ile ilgili sınıfa bir sunum yapar. Katılımcılara model oluşturma esnasında aşağıdaki sorular sorularak rehberlik yapılır.

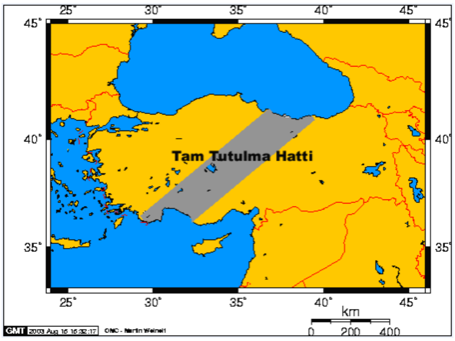
- ✓ Dünya, Güneş ve Ay'ın hareketleri boyunca çizdiği yörüngelerin şekli nasıldır?
- ✓ Bu yörüngeler birbiri ile çakışmakta mıdır yoksa yörünge düzlemleri arasında fark var mıdır?
- ✓ Tutulmanın gerçekleşmesi için bu dünya ve ay'ın yörünge düzlemi çakışmalı mıdır?

Açıklama: Açıklama kısmında katılımcılara Ay, Güneş, Dünya'nın özellikleri, hareketleri, birbirlerine göre konumları, güneş tutulmasının Ay'ın hangi evresinde gerçekleştiği ve Güneş tutulması için gerekli şartlar anlatılır. Son olarak 26 Mart 2006'da Türkiye'de gerçekleşen güneş tutulmasının videosu izlettirilir.

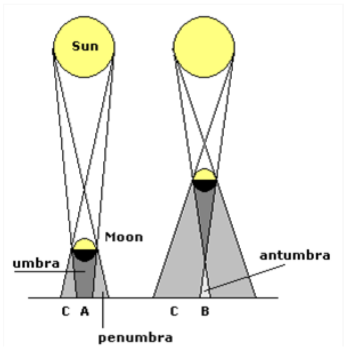
Ayrıntılandırma: Katılımcılardan öğrendiklerini kullanarak gruplar halinde çalışmaları ve ay tutulmasının nasıl gerçekleştiğini açıklayan bir model oluşturmaları istenir. Gruplara el feneri, çubuk, oyun hamuru ve pinpon topu verilir. Her grup modelini tamamladıktan sonra ay tutulmasının nasıl gerçekleştiği ile ilgili açıklamasını sınıfa sunacaktır. Katılımcılar ayın neden evreleri olduğunu, tutulma kavramını, tutulma gerçekleşmesi için gerekli şartları kavradıkları için onlardan bu aşamada yeterli bir açıklama beklenmektedir.

Son olarak ay tutulmasının videosu izlettirilir.

Ana Değerlendirme:



1. 29 Mart 2006 yılında tam güneş tutulması gerçekleşmiş ve bu tutulma Türkiye'de sadece bazı bölgelerden gözlemlenebilmiştir. Tutulmanın Türkiye'nin tüm bölgelerinde gözlemlenememesinin sebebi nedir?



2. Aşağıdaki şekle göre A, B ve C bölgelerinde bulunan gözlemci bu noktalardan baktığında güneşi ve ayı nasıl görür ve her bölgede gerçekleşen tutulmanın türü nedir?

ETKİNLİK-4
YARIŞAN TEORİLER:
EVRİM SÜRECİNDE LAMARCK VE DARWİN

Konu: Adaptasyon ve Evrim

Gereken Süre: 2 ders saati

Gerekçe:

Bilim insanları tanımlanırken çoğunlukla nesnel oldukları vurgulanır. Bilimsel bir araştırma ile meşgul oldukları zaman, kendi kişisel önyargılarını, bakış açılarını ve inançlarını bir kenara bıraktıkları düşünülür. Bu nesnelliğin, onların nesnel gözlemler yürütmelerine imkan verdiğine inanılır. Bu düşünceye göre bilim insanları teoriden bağımsız gözlemler yaparlar; olayları olduğu gibi tanımlayıp ölçüm yaparlar (Lederman ve Abd-El-Khalick, 1998). Bu iddiaları kabul etmek cazip olabilir. Öte yandan bilim tarihi, bunların aksini gösterecek örneklerle doludur.

Örneğin, bilim teori yüklüdür. Teori yüklülük, bir teoriyi önvarsayma; bir teori olmadan ifade edilememe durumudur. Örneğin bir gözlem ifadesi, salt gözlem içermeyip, o konuda öne sürülen bir kuramın doğruluğunu açık veya örtük biçimde kabul ediyorsa, bu gözlem teori yüklüdür. Bir kısım düşünürlere göre, herhangi bir kuramsal arka plan olmadan gözlem yapma imkansız olduğu için her tür gözlem teori yüklüdür, teoriden bağımsız gözlem mümkün değildir.

Gözlemlerin çeşitliliği ya da niteliği gözlemcinin kuramsal bilgilerine bağlıdır. Gözlemler teori yüklü olduğu için, inançlarınız – sahip olduğunuz teorilerle de şekillenen – neyi gözlemleyeceğinizi belirler. Dolayısıyla farklı teorilerin taraftarları farklı gözlemler yapacaktır.

Bilimde yaptığımız açıklamaların aşağı yukarı tamamı teori yüklüdür. Örneğin, bir elektronun bir yüzeye çarptığını iddia etmek, ekranda gördüğünüz beyaz bir lekeye atfettiğiniz teorilerin sonucudur.

Öğrencilerin bu durumun farkında olmasını sağlamak bilimin nesnel olduğu ve ilerlediğiyle ilgili mitleri gidermede önemlidir.

Neye İhtiyaç Var?

- DNA dizilimlerini oluşturmak üzere 4 farklı renkten ataçlar.
- Teorileri tanıtmak ve bulguları kaydetmek üzere öğrenci çalışma kağıdı.
- Teorileri tanıtmak üzere teorilerin anlatıldığı sunum.

Nasıl Yapılır?

Katılımcılara verilen iki teori hazırlanan sunumla anlatılır. Katılımcılar gruplara ayrılır ve gruplardan teorilerden birini seçmeleri istenir. Katılımcılara seçtikleri teoriye uygun davranmaları gerektiği, verilerini her durumda teoriye uygun olarak yorumlamaları gerektiği belirtilir. Örneğin ortak ata teorisini benimsemiş olan gruplar canlıların ilişkisine yönelik hipotezler oluştururken her zaman ortak bir atanın varlığını hesaba katacaklardır, asla bir türün diğerine dönüşümünü düşünmeyeceklerdir. Aynı şekilde, türlerin dönüşümü teorisini savunan gruplar her zaman bir türün diğerine dönüştüğü teorisi üzerinde hipotezlerini kuracaklardır.

Katılımcılardan İlkel Canlı, İnsan, Goril ve Şempanze türlerinin benzerliklerine göre aralarında bir evrim ilişkisi kurmaları istenir. Katılımcılar bu ilişkileri hipotez olarak ifade edecekler ve verilen çalışma kağıdına yazacaklardır. Gruplardan birden fazla hipotez yazmaları ve hipotezleri yazarken tüm canlıları dikkate almaları istenir. Örneğin katılımcılar iki hipotezden birini insan ve şempanze arasında diğerini goril ve şempanze arasında kurmayacaklar, aksine bir hipotez tüm verilen canlılar arasındaki ilişkileri belirtecek nitelikte olacaktır.

Katılımcılar hipotezlerini yazdıktan sonra katılımcılara bu canlılara ait DNA örneklerinin verileceği söylenir. Her bir canlıya ait DNA dizilimleri katılımcılara gösterilir. Katılımcılardan bu DNA dizilimlerini daha iyi değerlendirebilmek, aralarındaki benzerlik ve farklılıkları görebilmek için DNA dizilimlerini verilen ataçlarla oluşturmaları istenir. Bu dizlimler oluşturulurken her renk ataç bir organik bazı temsil edecektir. (Örnek: A-Adenin organik bazı- rengi: kırmızı, G-Guanin organik bazı- rengi: yeşil, T- Timin organik bazı- rengi: turuncu, S-Sitozin organik bazı- rengi: sarı gibi).

DNA dizilimleri oluşturulduktan sonra katılımcılardan yazdıkları hipotezleri oluşturdukları DNA dizilimleri ile karşılaştırmaları istenir. DNA dizilimleri arasındaki benzerlik ve farklılıklar teorileri desteklemekte mi yoksa çürütmekte midir?

Bütün gruplar hipotezlerini test ettikten ve seçtikleri teoriye göre DNA dizilimlerinden nasıl bir sonuca vardıklarını yazdıktan sonra iki grup seçilir (farklı teorileri savunan gruplar) ve DNA dizilimlerinin onların teorisiyle nasıl açıklandığını anlatmaları istenir. Gruplar burada evrim süreci ile ilgili vardıkları sonucu şematize ederek anlatabilirler. Bu aşamalardan sonra bilimin doğası ile ilgili aşağıdaki sorular tartışmaya açılır.

Kaynak:

National Academy of Sciences (1998). “Investigating Common Descent: Formulating Explanations And Models”.

ETKİNLİK-5

UZAYDAN GELEN CİSİM:

BİLİMDE MODELLERİN YERİ VE ÖNEMİ

Konu: Bilimin Doğası

Gereken Süre: 2 ders saati

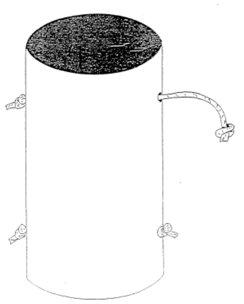
Gerekçe:

Bilimsel modellerin doğası ve modellerin bilimdeki rolü öğrencilerin anlamakta zorluk çektikleri ve bilimdeki modellerin gerçeğin birebir kopyası olduğu görüşü öğrencilerin arasında oldukça yaygın olan yanlış bir inanıştır. Öğrenciler bir model oluşturma süreci yaşayarak ve oluşturdukları modelin doğası üzerinde açık bir şekilde düşünerek modellerin bilimdeki yeri ve önemini doğru bir şekilde anlayabilirler.

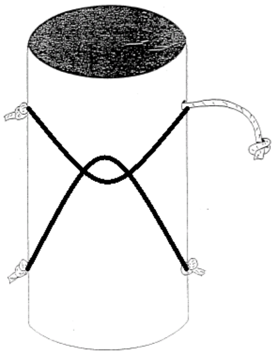
Neye İhtiyaç Var?

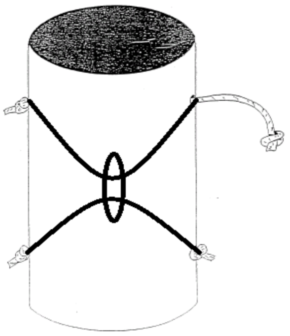
- Karton (karton alışveriş çantası da kullanılabilir)
- İp
- Makas
- Bant
- Yapıştırıcı

Nasıl Yapılır?



Öğrenme döngüsünün ilk aşaması olan keşfetme aşamasında ilk olarak katılımcılara yanda gösterilen cismin uzaydan dünyamıza düştüğü söylenir ve tüm sınıf görebilecek şekilde bu cisim üzerindeki ipler farklı noktalardan çekilir. Daha sonra katılımcıların görevlerinin bilim insanı olarak bu cismin içinde nasıl bir sistem olduğu ile ilgili bir model oluşturmaları olduğu söylenir. Sınıfta katılımcı sayısına göre 4-5 kişiden oluşan bilim insanı takımları oluşturulur. Takımlara gözlemlerini, hipotezlerini, hipotezlerini nasıl test ettiklerini kaydedecekleri ve cismin içinde nasıl bir sistem olduğu ile ilgili oluşturdukları modelleri çizecekleri çalışma kağıtları dağıtılır. Ayrıca katılımcılara kendi modellerini oluşturmaları için gerekli malzemeler sağlanır. Tüm katılımcılar çalışma kağıtlarını tamamlayıp bir model önerdikten sonra her bir grup kendi modelini ve bu modeli hangi gözlem, hipotez ve testlere dayandırarak oluşturduğunu açıklar. Ayrıca her gruba kendi modellerinin uzaydan gelen cisimle aynı şekilde çalışıp çalışmadığını da modelini sunarken inceleme fırsatı verilir. Sınıfta cismin içindeki sistem ile ilgili birden fazla model ortaya atılır. Gruplar tarafından önerilen muhtemel modeller;


Olası Model 1


Olası Model 2

Öğrenme döngüsünün ikinci aşaması olan terim tanıtımı aşamasında tüm gruplar modellerini sunduktan sonra sınıfta bu etkinliğe dayalı olarak bilimin doğası üzerinde bir sınıf tartışması yürütülür. Bu tartışma esnasında katılımcılara etkinlik ile ilgili çeşitli sorular sorulur ve etkinlik ve bilimin doğası arasında bağlantı kurulur. Öğrenme döngüsünün son aşaması olan kavram uygulaması aşamasında ise katılımcılara bilimin doğası hakkında öğrendiklerini yeni durumlara uygulama fırsatı sunulur. “Bilimsel modeller ile ilgili öğrendiklerinizden yola çıkarak birçok yerde yer alan atomun şekli ile ilgili çizimler hakkında neler söyleyebilirsiniz?”, “Bu çizimler atomu birebir yansıtmakta mıdır?”, “Atom modelleri ortaya atılırken bilim insanları modellerinde nasıl emin olmaktadırlar?”, “Öğrencilerinize atom modellerini anlatacağınız bir derste ulaşmak istediğiniz temel kazanımlar neler olur?”.

Kaynak:

Lederman, N. G., ve Abd-El-Khalick, F. (1998). Avoiding de-natured science: Activities that promote understandings of the nature of science. In W. McComas (Ed.), *The nature of science in science education: Rationales and strategies* (pp. 83–126). Newyork: Kluwer Academic Publishers.

ETKİNLİK-6
BİLİM TARİHİNDEN ÖRNEK OLAY:
FLOJİSTON VE MODERN KİMYANIN OLUŞUMU

Konu: Kimyasal Reaksiyonlar

Gereken Süre: 3 ders saati

Gerekçe:

Bilim tarihinde bazı bilimsel teoriler elde edilen bulgular neticesinde kullanılırlığını yitirmiş yerini yeni teoriler almıştır. Bu etkinlikte 18. yüzyılın başlarına kadar bilim insanları tarafından kullanılan ve kimyasal reaksiyonları özellikle yanma reaksiyonunun açıklayan "Flojiston" teorisinden bahsedilecek ve elde edilen yeni bulgular ışığında Flojiston teorisinin geçerliliğini yitirip yerine oksijenli yanma teorisinin kabul edilişi süreci anlatılacaktır.

Neye İhtiyaç Var?

- Plastik tabak
- Mum
- Su
- Beher
- Kağıt
- Magnezyum şerit
- Terazi
- Çalışma kağıdı

Nasıl Yapılır?

Bu etkinlikte bilim tarihinden örnek bir olay olarak yanmaya ilişkin oksijen teorisinin gelişimi kullanılarak katılımcıların bilimin doğasının boyutları hakkında argüman oluşturmaları, bu argümanlarını diğerleri ile paylaşmaları ve tartışmaları sağlanır.

Etkinlikte öncelikle katılımcılara Flojiston teorisi açıklanır. Flojiston teorisi 18.yy boyunca Lavosier yanma olayını açıklamak için oksijen teorisini ortaya atana kadar bilim topluluğu tarafından kabul gören bir teoriydi. Bu teoriye göre yanan cisimler flojiston içermekteydi ve yanma sırasında maddeden flojiston çıkmaktaydı. Daha sonra katılımcılardan Flojiston teorisinin kabul edildiği dönemdeki bilgi birikimine sahip olduklarını varsayarak ve "Eğer… ve … ise… ve/ama… bu yüzden…" akıl yürütme kalıbını kullanarak flojiston teorisini test etmeleri istenir.

Katılımcılar flojiston teorisini temel alarak;

1. Kapalı bir kapta mumun yanması sonucunda kaptaki havanın hacminde meydana gelecek değişimi,
2. Bir kağıt yandığında kağıdın kütlesinde meydana gelecek değişimi,
3. Bir metal (magnezyum şerit) yandığında metalin kütlesinde meydana gelecek değişimi,

tahmin ederler. Daha sonra bu tahminlerini deneysel olarak nasıl test edebileceklerini belirlerler ve planladıkları deneyleri gerçekleştirirler. Deneysel verileri elde eden katılımcılar gruplar halinde "Eğer… ve … ise… ve/ama… bu yüzden…" akıl yürütme kalıbını kullanarak flojiston teorisini destekleyen veya çürüten argümanlar oluştururlar.

Katılımcılar küçük grup ve tüm sınıf tartışması aracılığıyla oluşturulan argümanları ve karşı argümanları birbirleriyle paylaşırlar ve öne sürülen argümanların güçlü ve zayıf yönlerini değerlendirirler. Daha sonra, Lavoisier tarafından yapılan deneysel çalışmalar ve yanmaya ilişkin oksijen teorisi açıklanır ve o dönemde flojiston ve oksijen teorilerine ilişkin öne sürülen argümanlar sunulur. Katılımcılardan elde edilen deneysel verileri ve bilimsel akıl yürütme kalıplarını kullanarak öne sürülen argümanların güçlü ve zayıf yönlerini değerlendirmeleri ve hangi teorinin daha tatmin edici ve geçerli teori olduğuna karar vermeleri istenir.

Bu örnek olay ile katılımcılar oksijen teorisinin gelişimi sürecinde elde edilen deneysel verilerin, farklı bilim insanları tarafından öne sürülen argümanların ve karşı argümanların farkında olurlar. Sunulan örnek olayda bilimsel bilgilerin değişime açık olduğu, aynı gözlemlerin farklı bilim insanları tarafından farklı yorumlanabileceği, bilimde yaratıcılık ve hayal gücünün önemli olduğu, bilimsel bilginin ilerlemesi sürecinde genellikle birden fazla yarışan teori olduğu, bilim topluluğunun bu yarışan teoriler arasından seçim yapmasında argümantasyonun önemli bir rolü olduğu vurgulanır.

ETKİNLİK-7
DNA'NIN KEŞFİ

Konu: DNA ve Genetik Kod

Gereken Süre: 4 ders saati

Gerekçe

Fen eğitiminin genel vizyonu bireyleri fen okuryazarı olarak yetiştirmektir. Öğrencilerin istenen düzeyde bilimin doğası anlayışına sahip olmaları fen okuryazarlığı hedefine ulaşmak için gerekli ayrılmaz parçalardan biridir. Bu nedenle bilimin doğasının ne olduğunu bilen bireylerin yetişmesi Fen eğitiminin genel amaçlarına ulaşmasında sağlamış olacaktır. Bilimin doğası bilimsel bilginin doğasında var olan değer ve öngörüler olarak tanımlanmıştır. Bilimin doğası tanımı ile ilgili bilim insanları bir fikir birliğine varmamış olsalar da, öğrencilere öğretilmesi gereken bilimin doğası boyutları ile ilgili genel bir uzlaşma sağlanmıştır. Buna göre, öğretilmesi gereken boyutlar aşağıdaki gibi sıralanmıştır:

- Bilimsel bilgi değişime açıktır.
- Bilimsel bilgi gözlem ve deneylere dayalıdır-deney bilimsel bilgiye ulaşmanın tek yolu değildir.
- Bilimsel bilgi teori yüklüdür ve öznellik içerir.
- Bilim sosyal ve kültürel faktörlerden etkilenir.
- Bilimsel bilgi gözlemlerin yanı sıra çıkarımlara dayanır.
- Bilimde tek bir bilimsel yöntem yoktur.

Bilimin doğası fen okuryazarlığına ulaşmada önemli bir boyut olmasına rağmen yapılan çalışmalar öğretmen ve öğrencilerin bilimin doğası ile ilgili kavram yanılgılarına sahip olduğunu göstermiştir. Öğretmen ve öğrencilerin kavram yanılgılarını düzeltmek için açık-yansıtıcı bilimin doğası eğitimi etkili bulunmuştur. Öğretmenlerin bilimin doğası ile ilgili istenen düzeyde bir anlayışa sahip olmasının yanında, bilimin doğasını nasıl öğreteceklerini de bilmeleri gerekmektedir. Yapılan çalışmalar öğretmenlerin bilimin doğasını öğretebilmek için, etkinlik, bilim tarihi bilgisi ve çeşitli örnekler bilmeleri gerektiğini göstermiştir. Söz konusu etkinlik öğretmenlere bilimin doğası ile ilgili çeşitli boyutları öğretebilecekleri açık-yansıtıcı bir yaklaşımla hazırlanmış bir örnek sunmaktadır.

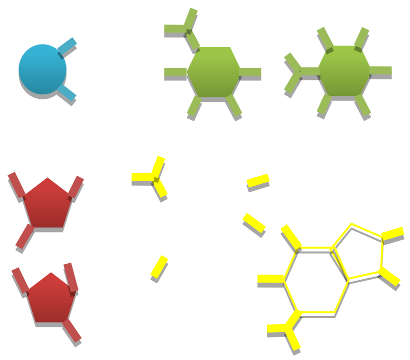
Neye İhtiyaç Var?

- Molekül modelleri
- İpucu kartları
- DNA ile ilgili video
- Rosalind Franklin yasam öyküsü ile ilgili video
- Senaryo kartları
- Kan testi serumları
- A Rh+ kan grubuna ait yarım test tüpü kan
- Kana bulanmış ufak bez parçaları
- Fenol fitaleyn çözeltisi
- Hidrojen peroksit çözeltisi
- Muz
- Bulaşık deterjanı
- Filtre kağıdı
- Alkol

Nasıl Yapılır?

Etkinlik 1

Etkinliğin birinci kısmında katılımcılar 4-5 kişiden oluşan gruplara ayrılır. Her gruba molekül modelleri verilerek belirli yapılardaki modelleri oluşturmaları istenir. Bu modellerin yapısı aşağıda verilmiştir:



Katılımcılar bu modelleri istedikleri kadar sayıda kullanarak bir molekül yapısı oluştururlar. Daha sonra katılımcılara bu moleküllerin molekül formülleri verilir. Katılımcılar molekül formüllerine bakarak oluşturdukları modeli gözden geçirirler.

Etkinlik 2

Etkinliğin ikinci kısmında katılımcılara DNA'nın yapısı ile ilgili bir video izletilir. Bu video sonrasında katılımcılar aşağıdaki yöntemle muzdan DNA sentezi yaparlar:

- Bir muz ikiye bölünür ve yarısı miksere atılır.
- Mikserdeki muzun üzerine 1 bardak musluk suyu eklenir ve 20 saniye boyunca iyice pürüzsüz bir hal alana kadar mikserde çırpılır.
- Muz püresinin üzerine 4 çay kaşığı bulaşık deterjanı eklenir. Köpürtmemeye özen gösterilir çünkü köpürmenin DNA moleküllerinin kırılmasına neden olabileceği belirtilir.
- Bir kasenin içine huni şekline getirilmiş kahve filtresi yerleştirilir.
- Muzlu şampuan karışımı bu filtreye yavaşça dökülür kasenin içinde 2-3 çay kaşığı karışım birikene kadar beklenir.
- 4 çay kaşığı buzda soğutulmuş alkol ince uzun bir cam tüpe koyulur ve filtrelenmiş karışım çay kaşığıyla yavaşça üzerine eklenir
- Birkaç dakika içerisinde beyaz bir bulut oluşur. Kürdanla bu bulut alınır ve DNA böylece izole edilmiş olur.

Katılımcılara DNA'nın yapısını daha iyi inceleyebilmek için isterlerse bu DNA' yı koyu renkli bir karta yerleştirebilecekleri, kurudukça ipliksi yapısını daha iyi fark edebilecekleri söylenir.

Etkinlik 3

Etkinliğin üçüncü kısmında katılımcılara Rosalind Franklin'in DNA'nın yapısının keşif sürecinde içinde bulunduğu sosyal ve akademik konumunu anlatan bir makale verilir. Katılımcılar bu makaleden sonra derse aynı konulu bir video izleyerek başlarlar. Videodan sonra katılımcılara Franklin'in yaşadığı dönemin onun bilimsel çalışmalarına olan etkisiyle ilgili sorular yöneltilir. (Bilimin her zaman nesnel ilerlemediği, bilim insanlarının akademik ve kültürel birikimlerinin onların çalışma yöntemlerini ve vardıkları sonuçları etkileyebileceği etkinlikle bağdaştırılır).

Etkinlik 4

Etkinliğin dördüncü kısmında katılımcılara bir senaryo verilir. Bu senaryoya göre denizin kenarında bir adamın cesedi bulunur.

İlk aşamada katılımcılar bu olayın cinayet mi yoksa intihar mı olduğu anlamak için cesedin kıyafetinde bulunan kırmızı lekelerin kan olup olmadığını test ederler. Bunun için adli tıp uzmanları tarafından kullanılan Kastle-Meyer testini araştırıp bulmaları ve gerçekleştirmeleri gerekir. Bulamayan gruplara aşağıdaki reaksiyonu içeren ipucu kartı verilir. Test aşağıdaki biçimde ilerlemektedir:

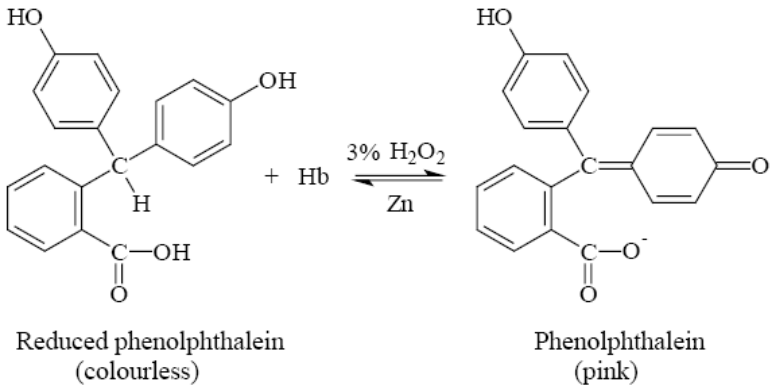


Figure 2 - Oxidation of reduced phenolphthalein by haemoglobin and peroxide

Bu reaksiyona göre katılımcılar indirgenmiş fenol fitaleyn çözeltisini kırmızı leke bulunan ve kan olduğu şüphelenilen kumaş parçalarına damlatırlar. (Kumaşta bulunan leke kan lekesi olduğundan reaksiyon gerçekleşti ve kumaş pembe bir renk alır).

Bu durumu tespit eden gruplar senaryoda ikinci aşamaya geçerler. Senaryonun ikinci aşamasında kumaşta kan lekesi olarak belirlenen kanın maktule mi yoksa bir başkasına mı ait olduğunu belirlemek gerekmektedir. Bu nedenle maktulden alınan kanın ve kumaşta bulunan kanın grubunu belirlemek için kan grubu testi yapılır. Bu amaçla kan grupları bilinen maktulun yakınları ve arkadaşlarının bir listesi kan grubu testinden sonra verilir. Kan grubu testini gerçekleştiren gruplar kanın maktule değil bir başkasına ait olduğunu tespit eder ve şüphelilerin sayısını kan grubuna göre azaltırlar. Bu aşamada yapılan olan kan grubu testi aşağıdaki şekilde gerçekleştirilir:

- Kandan, lam üzerine hazırlanan yuvarlaklar içine birer damla koyulur.
- Sonra ~A~ yuvarlağına anti - A, ~B~ yuvarlağına da anti - B serumu ilave edilir.
- Her iki yuvarlak için ayrı ayrı kürdan kullanarak, kan ve serumu birbirine karıştırılır.
- Kan damlalarında, kan hücrelerinin kümelenip kümelenmediği gözlemlenir. (Hangi kanda kümelenme olursa, kanın grubunun damlatılan serumun adında

olduğu belirtilir. Yani A ve B grubu. Her iki kandamlasında da kümelenme varsa, kan grubunun ~AB~ olacağı söylenir. Şayet iki damlada da kümelenme yoksa kan grubunun ~0~ (= sıfır) olacağı belirtilir.)

Bu aşamadan sonra gruplar şüpheli sayısını 3'e indirirler. Ancak henüz katil bulunamaz. Yapılacak son test DNA testidir. Bunun için 3 şüpheliye ait DNA dizilimleri ve kumaşta bulunan kana ait DNA dizilimi katılımcılara verilir. Katılımcılar dizilimler arasındaki benzerlikleri tespit ederler ve benzerliğin en yüksek olduğu DNA dizilimine sahip kişiyi sanık olarak belirlerler. (Bu etkinlikte katılımcılar tıpkı bir adli tıp uzmanı gibi çalışarak bilimsel bir sürecin izleyişine tanık olurlar. Bu yolla tek bir bilimsel yöntem olmadığını, birçok farklı yöntemin bilimsel sonuçlara ulaşmak için kullanıldığı etkinlik ile bağdaştırılır).

ETKİNLİK-8
DÜŞÜNCE DENEYLERİ

Konu: Kuantum Fiziği

Gereken Süre: 3 ders saati

Gerekçe:

Bilim ile ilgili mitlerden bir tanesi de deneysiz bilim olmayacağıdır. Ancak bilimde bazı deneyler vardır ki laboratuvarda değil insan zihninde gerçekleştirilmiştir. Bu düşünce deneyleri bilimde fiziksel anlamda deney yapmanın şart olmadığını bize göstermektedir.

Neye İhtiyaç Var?

- "A Beautiful Mind" isimli filmden alınmış, düşünce deneyini gösteren sahne (2dak. 24 sn.)
- Düşünce deneylerini anlatan Power Point sunumu.
- Galileo'nun düşünce deneyini gösteren Flash Animasyonu.
- Dr. Quantum: Çift Yarık Deneyi Animasyon Çizgi Filmi.
- Schrödinger'in Kedisi düşünce deneyini temsil etmek üzere kurulan düzenek:

  Gerekli malzemeler:

  a. Karton kutu (Bisküvi kutusu, veya koli)

  b. Oyun hamuru veya kil

  c. Kediyi temsil eden peluş oyuncak (herhangi bir hayvan olabilir)

d. Şurup kutusu (karton) veya eşdeğer boyutlarda bir kutu.

e. Bir paket pamuk

f. Koli bandı

g. Para bandı.

h. Makas, ataş.

Schrödinger'in Kedisi düzeneğinin hazırlanması:

1. Kutunun açılabilen iki yüzünden birisi koli bandı ile sağlamlaştırınız, diğer yüzündeki kanatlar ise kesiniz. Bu yüzeyi tamamen kapatacak şekilde kartondan kapak yapınız.

2. Kartonun açık olan yüzeyi sınıfa dönük olacak şekilde tutulduğunda üst tarafta kalan yüzeye 5-6 cm çapında dairesel bir delik açılır (Şekle 1'e bakınız).

3. Kutunun iç tarafını pamuk ile kaplayınız.

4. Kartondan 25- 20 cm uzunluğunda boru şeklinde sopa yapınız. Bu sopayı uzun bir tel ile kartonun üst yüzeyine iç taraftan tutturunuz.

5. 15 cm çapında karton daire kesiniz ve bunu sopanın bir ucuna tutturunuz.

6. Pelüş oyuncağı 10 cm yüksekliğinde bir cismin üzerine koyarak sopanın diğer ucuna iliştiriniz. Sopanın karton olan ucuna bir cisim çarptığında diğer ucu kediyi yerinden oynatıp düşürecek şekilde ayarlayınız.

7. Şurup kutusunu Şekil 2'deki gibi tam ortadan ikiye kesiniz. Ayrı bir kartondan, kutuların açık kısımlarını kapatacak boyutta iki adet parça kesiniz.

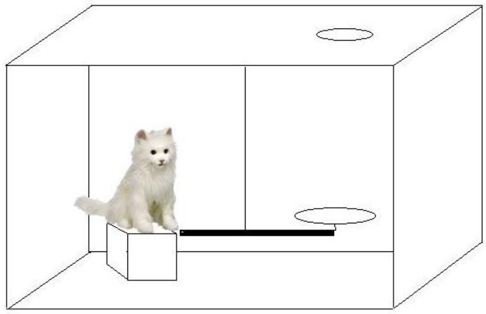
8. Oyun hamurunu iri bir bilye büyüklüğünde küre şeklinde yuvarlayın. Üzerini para bandı ile kaplayınız.

Nasıl Yapılır?

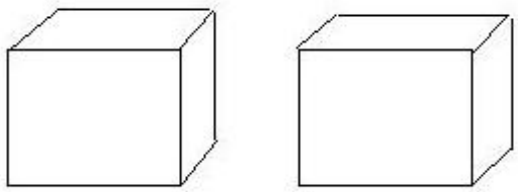
Etkinliğe, film gösterimi ile başlanır. Sonra sunum gösterilir. Sunumun Galileo'nun düşünce deneyini anlattığı kısımda sunuma ara verilip Galileo'nun düşünce deneyini anlatan animasyon gösterilir. Animasyon bittikten sonra Galileo'nun düşünce deneyinin bilime katkısı tartışılır. Daha sonra sunuma devam edilir. Sunum bittikten sonra Dr. Quantum: Çift Yarık Deneyi Animasyon Çizgi filmi gösterilir. Ardından Schrödinger'in Kedisi Düşünce Deneyi hakkında bilgi verilir ve daha önceden hazırlanmış Schrödinger'in kedisi düzeneği öğretmen adaylarına tanıtılır. Düzeneğin mantığı ihtimal hesaplarına dayanır. Elektronu temsil eden oyun hamurundan hazırladığımız topumuz % 50 ihtimalle delikten içeri düşer veya düşmez.

Etkinliğin Yapılışı:

1. Top şurup kutularından birisinin içine konulur. Kutular eski getirilip bantlanıp tek kutu haline getirilir. Kutu sallanır. Her hangi bir anda masanın üzerine konulur ve bantları sökülür. Daha önceden kesilen iki adet karton parçası ile açık olan kısımları kapatılır. Katılımcıların iki yarım kutudan hangisinde top olduğu gösterilmez.
2. Katılımcılardan birisine yarım kutulardan birisi seçmesi istenir. Seçilen kutuda % 50 ihtimalle top vardır ya da yoktur.
3. Büyük kolinin içine kedi ve düzenek yerleştirilir ve açık olan kısım kapatılır. İçeride olanların görünmemesi sağlanır.
4. Seçilen şurup kutusunun açık ucu kolinin üzerideki deliğe yerleştirilir. Kutuyu kapatan karton parçası yavaşça çekilir. Böylece eğer kutuda top varsa delikten düşmesi sağlanır (Top düştüğünde ses çıkmaması gerekir. Ses çıkarsa etkinlik tekrarlanır).
5. Katılımcılara koli içerisindeki kedinin ölüp ölmediği sorulur. Animasyon filminde bahsedilen durum ile ilişkilendirilip bu düşünce deneyinin durumu nasıl açıkladığı hakkında tartışma yapılır.



Şekil 1



Şekil 2

ETKİNLİK-9
SÜPER İLETKENLİK

Konu: Süper iletkenlik

Gereken Süre: 2 ders saati

Gerekçe:

Bilim ile ilgili mitlerden bir tanesi olan "Hipotezler önce teori olur, ardından kanun" ile ilgili yapılan bu etkinlikte, bu mitin ne yönden yanlış olduğu üzerinde durulmaktadır.

Neye İhtiyaç Var?

- Süper iletkenlik özelliği kazanan bir metalin nasıl davrandığını gösteren bir video.

Nasıl Yapılır?

Etkinlikte katılımcılara açıklamaları istenilen bir olayın videosu izlettirilir. Bu videoda süper iletkenlik özelliği kazanan bir metalin nasıl davrandığı gösterilmektedir. Katılımcılar gözlemledikleri olayın sebebini açıklamaya çalışırlarken öncelikle ön bilgilerini kullanmaya çalışırlar. Ön bilgilerinin yetersiz olduğu durumlarda katılımcılara yeni bilgiler verilir ve tekrar açıklama yapmaya yönlendirilir. Metalin her bir davranışı için ayrı bir gözlem yapmaları sağlanır. Örneğin süper iletken metalin soğukta ve sıcakta (sıvı azot içerisinde ve dışında) diğer bir metalle olan etkileşimleri ya da süper iletkenlik özelliği kazanan metalin diğer metale yaklaştırıldığında neler olduğu sırayla gösterilir ve bunlara sırayla açıklama getirmeleri istenir. Böylece katılımcıların daha önce sahip oldukları bilgileri yeni gözlemleri açıklamaya çalışırlarken kullanmaları sağlanır.

Bütün bunlardan sonra katılımcılar ile açık düşündürücü bir yaklaşım kullanılarak etkinlik süreci ve bilimsel çalışma süreci arasındaki örtüşmeler hakkında tartışmalar yürütülür. Katılımcılar daha önce hiç görmedikleri bir olayı açıklarlarken ön bilgilerini kullandıkları hatırlatılıp bilimde de böyle olduğu; bir olayın mümkün olan en az sayıda prensip kullanılarak açıklanabildiği bunun bilimsel bilginin sadelik, basitlik (parsimonious) özelliği olduğu tartışılır. Birbiri ile ilişkili peş peşe gözlemler yapıldıktan ve her biri açıklanmaya çalışıldıktan sonra ortaya süper iletkenlik teorisi çıkarılır. Peki, bu teori tek başına duran, diğer teorilerden bağımsız bir teori midir?

Hayır, süper iletkenlik teorisi başka teorilerle de alakalıdır. Örneğin süper iletkenlik teorisini elektromanyetik teori içinde ele alabiliriz, bunların ikisini de mekanik teori içinde düşünebiliriz, BCS teorisini süper iletkenlik teorisi içinde düşünebiliriz. Buradan yola çıkılarak bilimsel bilginin tüm dalları ve alanları ile bir bütünlük oluşturma özelliği olduğu üzerinde tartışılır. Bilimsel bilgiler ortaya çıkarken bazen, etkinlikte de olduğu gibi, deneyden yola çıkıp teorimizi oluşturabildiğimizi bazen de teoriden yola çıkılıp deneylerin sonra yapıldığı üzerinde konuşuldu. Bütün bunlar düşünüldüğünde teorinin yabana atılacak önemsiz, basit bir kelime olmadığı vurgulanır. Bilimin doğası hakkında mitlerden birisi olan; "teori üzerinde tüm bilim insanları tarafından görüş birliği sağlandığında kanuna dönüşür" ifadesinin ne yönden yanlış olduğu üzerinde tartışılır. Bilimsel teorinin deney, gözlem, çıkarım, sezgi, hipotez, mantık, matematiksel teknik ve araçlar, genelleme, ilke, ve kanunlarla, birlikte eldeki problemler dizgisine yönelik bilim insanlarının ön görü ve yorumlarını da içeren kapsamlı ve bütünlüklü bir açıklama olduğu belirtilir.

Kaynak:

Taşar, M.F. (2010). "Exempliflying the tentativeness of scientific knowledge in the history of modern physics and utilizing vignettes in assessing understandings". In Inglo Eilks and Bernd Ralle (Eds.), *Contemporary Science Education –Implication from Science Education Research about Orientations, Strategies and Assessment*. Shaker Verlag Aachen.

ETKİNLİK-10

BİLİM VE TEKNOLOJİ:

SEHARAP PEŞİNDE – TASARIMLAR YARIŞIYOR

Konu: Bilim ve Teknoloji

Gereken Süre: 3 ders saati

Gerekçe:

"Bilim ve teknoloji hemen hemen birbirinin aynıdır." ifadesi bilimin doğası ile ilgili mitlerden bir tanesidir. Öğrenenlerin bilimin doğası hakkında daha doğru anlayışlar geliştirebilmesinin önemli bir öğesi "bilim ve teknoloji" kavramlarını ayırt ederek bu kavramların birbirlerini ile etkileşimlerini, benzerliklerini ve farklılıklarını algılayabilmeleridir. Bu nedenler öğrenenlerin bilim ve teknoloji hakkında düşündürücü deneyimler yaşayarak bu kavramlar üzerinde derinlemesine düşünmelerini sağlamak önemlidir.

Neye İhtiyaç Var?

- Değişik boyutlarda poşetler (çöp poşeti, buzdolabı poşeti gibi)
- Tel
- Bambu Hobi tahtaları (1 mm, 2 mm geniş tahta veya ince, uzun sopalar)
- Değişik boyutlarda mumlar (doğum günü mumları, süs mumları)
- Makas
- Maket bıçağı
- Kargaburnu
- Pense
- İçecek pipeti
- Bant, Yapıştırıcı
- Küçük makaralı sistem
- İp, İğne
- Çeşitli kağıtlar

Nasıl Yapılır?

Bu etkinlikte katılımcıların birbiriyle yakından ilişkili olan, birbirini etkileyen ancak farklı olan bilim ve teknoloji ile ilgili anlayışlarını ilerletmek amaçlanmaktadır. Etkinlikte katılımcılara bir senaryo içinde çiftçilik yapan bir topluluğun günlük yaşam problemi tanıtılır ve katılımcılardan yüksek dağlara ulaşımı daha kolay ve güvenli bir hale getirecek bir araç tasarlamaları istenir. Katılımcılara tasarladıkları aracın bir modelini yapabilmeleri için alüminyum folyo, model tahtaları, bant, yapışkan, tel, kağıt gibi çok çeşitli malzemeler verilir ve tasarladıkları aracın bir modelini oluşturarak bu modeli test etmeleri istenir.

Gruplar halinde çalışan katılımcılar sıcak hava balonu, teleferik, raylı ulaşım sistemi gibi çeşitli tasarım modellerini geliştirebilirler. Geliştirdikleri modelleri test eden katılımcılar, test sonucuna göre gerekli gördükleri değişiklikleri yaparak modellerine son halini vermeye çalışır. Böylece katılımcılara aktif bir şekilde teknolojik tasarım süreci yaşatılır.

Etkinlikten sonra, katılımcılarla yaşadıkları sürecin bilimsel bir araştırma süreci mi, yoksa bir teknolojik tasarım süreci mi olduğu tartışılır. Daha sonra katılımcılara "Bilim ve teknoloji aynı şey midir? Neden?" sorusu sorularak onların bilim ve teknoloji hakkındaki düşünceleri alınır. Bu tartışmadan sonra, bir çalışma kağıdıyla katılımcılardan bilim ve teknolojiyi amaç, süreç ve ürün yönünden karşılaştırarak değerlendirmeleri istenir.

Yaşadıkları deneyimler üzerinde düşünen katılımcıların düşünceleri alınarak bilimin amacının insanların doğal dünya ile ilgili merak edilen sorulara cevap aramak olduğu, teknolojinin amacının ise insanların çevreye uyum sağlamaya çalışırken karşılaştıkları problemlere çözüm aramak olduğu ortaya konulur. Ayrıca, bilimsel araştırma sürecinde hipotez kurma ve deney yapma gibi bilimsel sorgulama stratejileri uygulanırken teknolojide tasarım yapma, inşa etme ve test etme gibi problem çözme stratejilerinin uygulandığı vurgulanır. Ürün yönünden değerlendirildiğinde ise bilimsel araştırmalar sonucunda doğal dünyadaki olgular hakkında açıklamalar oluşturulduğu, teknolojik faaliyetlerin ürününün ise insanların ihtiyaçlarına, uyum problemlerine çözüm getiren tasarımlar olduğu irdelenir.

Çalışma Kağıtları:

BİLİM VE TEKNOLOJİ

Adı-Soyadı:

Numara:

1. Bilim nedir? Örnek vererek açıklayınız.

2. Teknoloji nedir? Örnek vererek açıklayınız.

3. Bilim ve teknoloji arasında bir ilişki var mıdır? Varsa nasıl bir ilişki vardır? Örnek vererek açıklayınız.

4. Bilimi teknolojiden, teknolojiyi bilimden ayıran bir farklılık var mıdır? Varsa nedir? Örnek vererek açıklayınız.

SEHARAP PEŞİNDE

(Tasarımlar Yarışıyor)

Yaşadığınız yerleşim biriminde insanlar geçimlerini *Seharap* bitkisi yetiştirerek sağlıyor. Ancak bu bitki çok yüksek dağların zirvesinde yetişiyor. Bulunduğunuz yerin etrafı yüksek dağlarla çevrili ve insanlar bir yıl içinde bu dağlara yüzlerce defa çıkıp iniyorlar. Ne yazık ki, dağların zirvesine çıkarken günlerce süren yolculuklar çok tehlikeli ve bazen ciddi yaralanmalar olabiliyor.

Siz, bir araç geliştirerek dağlara ulaşımı daha kolay ve güvenli bir hale getirebileceğinizi düşünüyorsunuz. Zihninizde birçok farklı araç tasarladınız; şimdi yapmanız gereken bir model geliştirip test ederek düşündüğünüz tasarımın uygun olup olmadığını bulmak.

"*Bir elin nesi var iki elin sesi var*" diyerek, arkadaşlarınızın farklı düşünce, deneyim ve becerilerinden yararlanmanın bu süreci hızlandıracağına karar verdiniz ve 6 kişilik bir grup oluşturdunuz. Amacınız en kısa sürede en yükseğe çıkan bir araç tasarlamak. Arkadaşlarınızla kullanabileceğiniz malzemeleri topladınız ve şimdi sıra sizde!

SEHARAP PEŞİNDE TASARIM SÜRECİMİZ-1

Tasarım Grubumuzun Üyeleri:

1 Amacınız

2 Konu hakkındaki araştırmalarınız, önbilgi ve deneyimleriniz

3 Olası Çözümler

4 En olası çözüm / Bu çözüm için gerekli malzeme, araç ve gereçler

Bu malzemeleri tercih etmenizin nedeni?

5 Tasarladığınız aracın modelini çizin ve modelinizi yapın

6 Oluşturduğunuz model ile yaptığınız ön denemenin sonucu

7 Amacınıza ulaştınız mı?

Evet ➡ Ulaştığınız çözümü arkadaşlarınızla paylaşın

Hayır ➡ Tasarımınızı geliştirmek için hangi değişiklikler yapılmalı? Niçin?

SEHARAP PEŞİNDE TASARIM SÜRECİMİZ-2

Tasarım Grubumuzun Üyeleri:

5 Düşündüğünüz değişikliklerle tasarladığınız yeni modeli çizin ve modelinizi yapın	**6** Oluşturduğunuz model ile yaptığınız ön denemenin sonucu	**7** Amacınıza ulaştınız mı? Evet ➡ Ulaştığınız çözümü arkadaşlarınızla paylaşın Hayır ➡ Tasarımınızı geliştirmek için hangi değişiklikler yapılmalı? Niçin?
5 Düşündüğünüz değişikliklerle tasarladığınız yeni modeli çizin ve modelinizi yapın	**6** Oluşturduğunuz model ile yaptığınız ön denemenin sonucu	**7** Amacınıza ulaştınız mı? Evet ➡ Ulaştığınız çözümü arkadaşlarınızla paylaşın Hayır ➡ Tasarımınızı geliştirmek için hangi değişiklikler yapılmalı? Niçin?

MUCİT Mİ? BİLİM İNSANI MI?

? Siz bu süreçte kendinizi bir bilim insanı gibi mi hissettiniz yoksa bir mucit gibi mi? Neden? ?

Bilim ve Teknoloji aynı şey midir? Cevabınızın nedenini açıklayınız?

BİLİM VE TEKNOLOJİ

Bilimin ve teknolojinin amacı nedir? Bilimsel araştırmalarda ve bir teknoloji geliştirilirken süreç içinde neler yapılır? Bilimin ve teknolojinin ürünleri nelerdir?

	Bilim	Teknoloji	
Amaç			Amaç
Süreç			Süreç
Ürün			Ürün

BİLİM VE TEKNOLOJİ BİRBİRİNİ NASIL ETKİLER?

Bence, geçmişte de günümüzde de bilimsel gelişmelerin esas yürütücü gücü teknolojidir. Teknoloji olmasaydı birçok bilimsel keşif olmazdı. Mikroskop ve teleskopu düşün mesela.

Hayır yanılıyorsun. Bilim insanlarının çalışmaları olmasaydı hiçbir teknoloji geliştirilemezdi. Mesela katot ışınları bulunmasaydı televizyon olabilir miydi?

? Siz ne düşünüyorsunuz? ?

Hem geçmişteki bilimsel ve teknolojik gelişmeleri hem de günümüzdeki durumu dikkate aldığınızda aynı şeyi mi söyleyebilirsiniz?

SEHARAP PEŞİNDE

Adınız Soyadınız:

Bu etkinlikten önce bilim ve teknoloji hakkında ne düşünüyordunuz?

Bu etkinlik, bilim ve teknoloji hakkındaki görüşlerinizi değiştirdi mi? Değiştirdiyse nasıl bir değişim oldu?

APPENDIX C

PCK FOR NOS ACTIVITIES

SCIENCE TEACHING ORIENTATION CLASS
NEDEN FEN ÖĞRETİYORUZ?:
FEN ÖĞRETİMİ AMAÇLARI ÜZERİNE DÜŞÜNME

Konu: Bilim okuryazarlığı ve bilimin doğasının bilim okuryazarlığı açısından önemi

Gereken Süre: 3 ders saati

Gerekçe:

Yapılan çalışmalar öğretmenlerin bilimin doğası hakkında yeterli düzeyde anlayışa sahip olsalar bile bilimin doğasını anlamayı önemli bir kazanım olarak içselleştirmediklerini göstermiştir. Ayrıca öğretmenlerin inançları ve amaçları bilimin doğası öğretimini etkileyen en önemli faktörler arasındadır. Bir öğretmen bilimin doğasını öğrenmenin öğrenci açısından öneminin farkına varmadıkça yaptığı öğretimde bilimin doğasını öğretmeyi amaçlarından biri olarak görmemektedir. Bu zorlukları aşmak için öğretmen eğitim programları bilimin doğasını öğretmenin önemini kavramalarında öğretmenlere ve öğretmen adaylarına yardımcı olmalıdır. Bu nedenle bu etkinliğin amacı öğretmenlerin veya öğretmen adaylarının neden fen öğretiyoruz sorusu üzerinde düşünmelerini sağlamak ve bilimin doğasını anlamanın bilim okuryazarlığına ulaşmak için önemli olduğunu fark etmelerini sağlamaktır.

Neye İhtiyaç Var?

- Bir bireyin sosyo-bilimsel bir konuda karar verme sürecini anlatan araştırmacılar tarafından hazırlanan 20 dakikalık bir video

Nasıl Yapılır?

Katılımcılar bir bireyin sosyo-bilimsel bir konuda karar verme sürecini anlatan videoyu izlemeden önce “Bir öğretmen adayı olarak sizce fen öğretiminin ve özellikle kimya öğretiminin amacı nedir? ve Sizce fen/kimya müfredatları doğrultusunda yapılan fen/kimya öğretimi ile yetiştirilen bireyler hangi tür bilgi, beceri vb. sahip olmalıdırlar?" sorularını cevaplayarak katılımcıların neden fen öğrettiklerinin ve fen öğretimine dair amaçlarının farkına varmaları sağlanır. Katılımcılar soruları cevapladıktan sonra bir annenin bebeğini domuz gribi aşısı yaptırıp yaptırmama konusunda karar verme sürecini ve neler yaşadığını anlatan videoyu izlerler. Videoyu izledikten sonra katılımcılar 4 veya 5 kişiden oluşan gruplara ayrılırlar. Her gruba videodaki bireyin bilinçli karar verebilmesi için sahip olması gereken bilgi/beceri/kazanımlarla ilgili iki öğretmenin argümanlarını içeren kavram karikatürleri sunulur. Kavram karikatürlerini oluşturan argümanlar;

- **Argüman 1:** Aşı, virüs vb gibi biyoloji kavramlarını daha iyi öğrenselerdi, bu kavramları günlük hayata uygulayabilir ve böylece domuz gribi aşısı konusunda daha bilinçli karar verebilirlerdi.
- **Argüman 2:** Birey olarak bilinçli kararlar verebilmeleri sadece aşı, virüs vb gibi biyoloji kavramlarını daha iyi öğrenmelerini değil aynı zamanda bilimin doğası hakkında da yeterli düzeyde anlayışa sahip olmalarını gerektirir.

Her grup kendi içinde hangi argümanı desteklediğini ve diğer argümanı nasıl çürüttüklerini gerekçeleri ile birlikte tartıştıktan sonra görüşlerini tüm sınıf ile paylaşır. Her grup görüşlerini paylaştıktan sonra katılımcılar ile bireyin sahip olması gereken bilgi türleri üzerinde, bilimin doğasını bilmenin bu süreçte onlara nasıl katkı sağlayacağı ve bilim okuryazarlığı üzerinde sınıf tartışması yürütülür. Sınıf tartışmasından sonra fen öğretimin amacı, bilim okuryazarlığı, bilim okuryazarlığının bileşenleri ve çeşitleri, bilimin doğasının bilim okuryazarlığı açısından önemi ve bilimin doğasının öğretilmesinin gerekçeleri ile ilgili bir sunum yapılır. Sunumdan sonra katılımcılar "Bu dersin vermek istediği mesaj nedir?, Fen öğretimi ile ilgili olarak bu derste neler öğrendiniz?, Bu derste öğrendikleriniz bir öğretmen olarak fen eğitimine bakış açınızı özellikle neden fen öğretiyorum sorusuna verdiğiniz cevapları nasıl değiştirmiştir? ve Bu derste öğrendikleriniz yapacağınız fen öğretiminizi özellikle fen okuryazarlığına ulaşma amacı ile dizayn edeceğiniz öğretimi öğretime dahil edeceğiniz konu alanları (fizik, kimya, bilimin doğası gibi) nasıl etkiler?" sorularını cevaplayarak fen öğretimine dair amaçlarını tekrar gözden geçirme fırsatı bulurlar.

Çalışma Kağıdı

Grup Üyeleri:...

Esra Öğretmen

Aşı, virüs vb gibi biyoloji kavramlarını daha iyi öğrenselerdi, bu kavramları günlük hayata uygulayabilir ve böylece domuz gribi aşısı konusunda daha bilinçli karar verebilirlerdi.

Burak

Birey olarak bilinçli kararlar verebilmeleri sadece aşı, virüs vb gibi biyoloji kavramlarını daha iyi öğrenmelerini değil aynı zamanda farklı konularda yeterli düzeyde anlayışa sahip olmalarını gerektirir.

Biz grup olarak..............................**öğretmenin görüşüne katılıyoruz.**
Çünkü...
....
....
....

KNOWLEDGE of LEARNER CLASS

ÖĞRENCİLER BİLİMİN DOĞASI HAKKINDA NE BİLİYORLAR?

BİLİMİN DOĞASI ÖĞRETİMİNDE KARŞILAŞILMASI MUHTEMEL ZORLUKLAR

Konu: Öğrencilerin bilimin doğası hakkında sahip oldukları yanlış inanışlar ve bilimin doğası öğretiminde dikkat edilmesi gereken hususlar

Gereken Süre: 3 ders saati

Gerekçe:

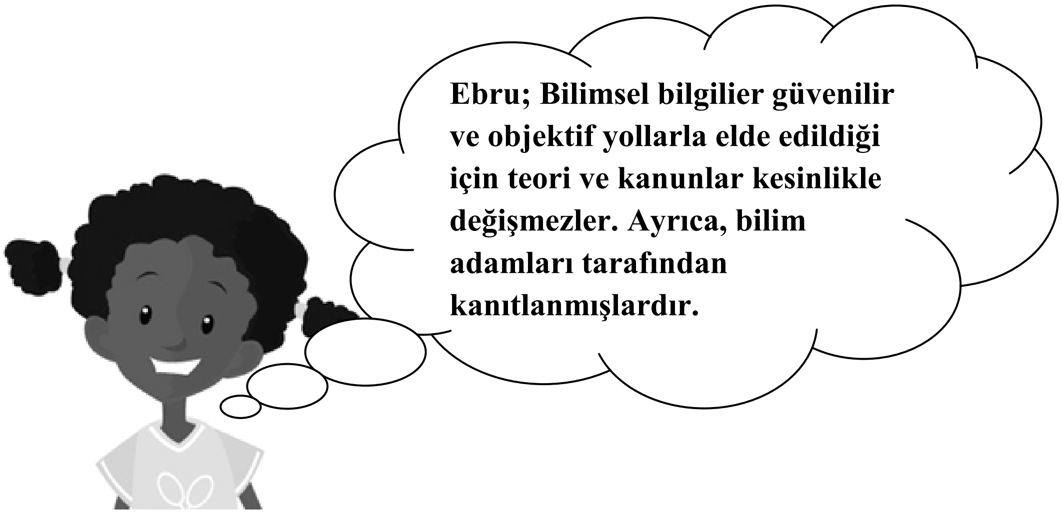
Öğretmenlerin bilimin doğasını öğretebilmeleri için sadece bilimin doğası hakkında yeterli anlayışa sahip olmaları yeterli olmamakla birlikte, aynı zamanda bilimin doğasının öğretimi için pedagojik alan bilgisine sahip olmaları gerektiği vurgulanmaktadır. Pedagojik alan bilgisinin beş bileşenini tanımlayan bir modele göre bileşenlerden birini öğretmenlerin öğrencilerin belli bir konu alanında sahip oldukları yanlış kavramalar bilgisi oluşturmaktadır. Öğretmenler etkili bir öğretim için öğrencilerin öğrenmek için neye ihtiyaç duyduklarını ve konu alanı ile ilgili mevcut yanlış kavramlarını göz önünde bulundurmalıdırlar. Bu nedenle bu etkinliğin amacı katılımcılar öğrencilerin bilimin doğası ile ilgili sahip oldukları yanlış inanışları ve bu inanışların kaynaklarını fark etmesini sağlamaktır.

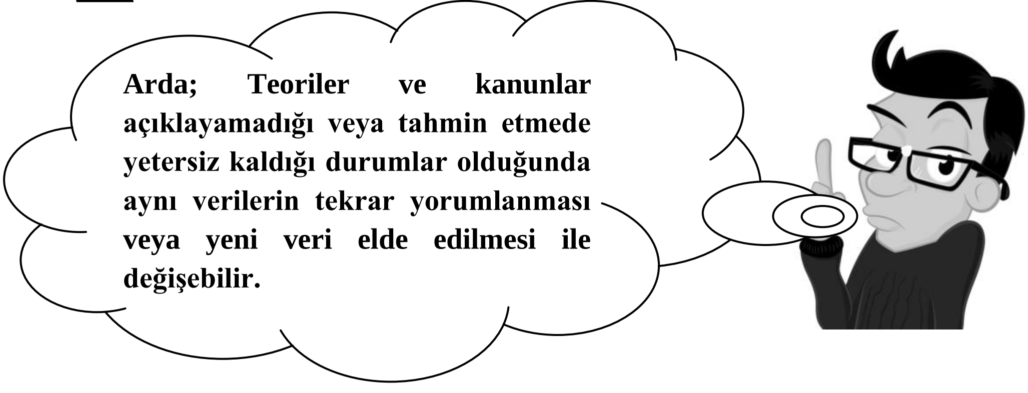
Neye İhtiyaç Var?

- Bilimin doğası ile ilgili mitleri (McComas, 1998)göz önünde bulundurarak hazırlanan 11 adet kavram karikatürü
- Kavram karikatürlerii aşağıda yer almaktadır.

“Bilimsel kanunlar ve buna benzer fikirler kesindir” miti ile ilgili karikatür

Öğretmen sınıfa elinde bilimsel bir dergi ile geldi. Bu dergideki bir makalede yapılan çalışmalar sonucunda gaz kanunlarının ve kinetik moleküler teorinin değişeceği ve bu teori ve kanunların yerine gazların davranışlarını tanımlayan ve açıklayan yeni kanunlar ve teoriler geleceği iddia ediliyordu. Bunun üzerine öğrenciler;





“Bilim adamları özellikle objektifdirler” miti ile ilgili karikatür

“Öğretmen Thomson’un elektronu keşfinden sonra elektronun yükünün nasıl hesaplandığını şu şekilde anlatmıştır. “O dönemde elektronun yükü üzerinde çalışmalar yapan bir çok bilim adamı bulunmaktadır. Bunlardan biri Millikan diğeri ise Ehranhaft’tır. Millikan ve Ehranhaft aynı deney sonuçları bulmalarına rağmen Millikan atomist görüşe (tüm maddelerin temel taneciklerden oluştuğu) sahip olduğu için deney sonuçlarının bazılarını ihmal etmiştir. Ehrenhaft ise antiatomist görüşe sahip olduğu için tüm deney sonuçlarını dikkate alarak hesaplama yaptığını anlatmıştır”. Bunun üzerine sınıftan bazı öğrenciler;

“Bilimsel bilgi kolay bir şekilde hemen kabul edilir” miti ile ilgili karikatür

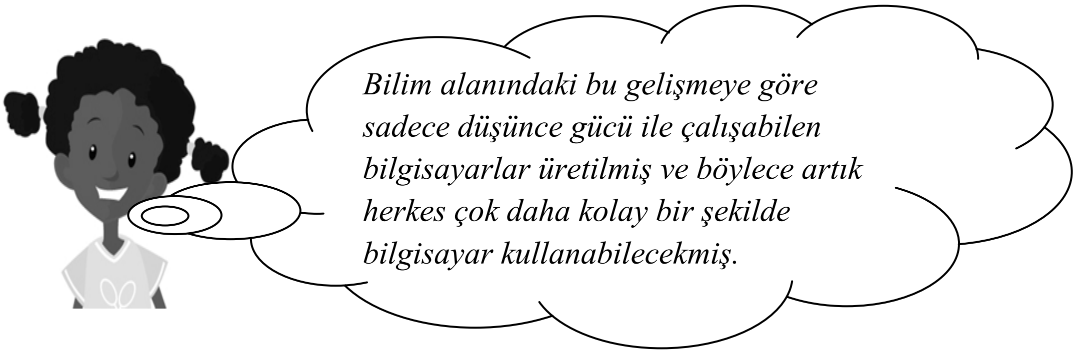
Öğretmen sınıfa bilimsel bir dergi ile geldi ve öğrencilere dergideki bir makaleden bahsetti. Dergide bilim adamlarının yaptıkları çalışma sonucunda modern atom teorisinin yerine maddeyi oluşturan temel tanecikler ile ilgili farklı bir teori buldukları yer alıyordu. Öğretmen öğrencilere bu teorinin hemen kabul edilip edilip edilmemesi gerektiğini sordu. Öğrenciler;

“Bilim tüm sorulara cevap verebilir” miti ile ilgili karikatür

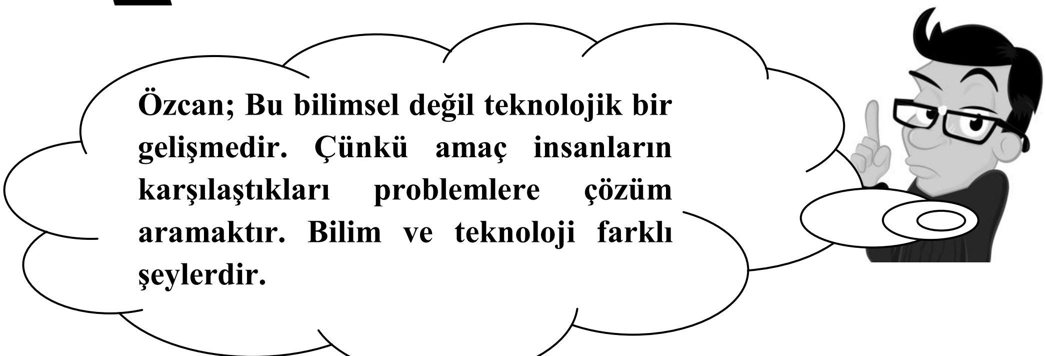
Öğretmen öğrencilere herhangi bir soru ile karşılaştıklarında bu soruya en güvenilir ve geçerli bir yanıtı bulmaları gerektiğinde nasıl bir metod izlemeleri gerektiğimi sorar.

"Bilim ve teknoloji aynı şeydir" miti ile ilgili karikatür

Ayşe öğretmenine bilim alanında duyduğu yeni bir gelişme olduğunu ve bunu sınıfla paylaşmak istediğini söyledi. Öğretmen Ayşe'ye izin verdi. Ayşe sınıfa şunu duyurdu:

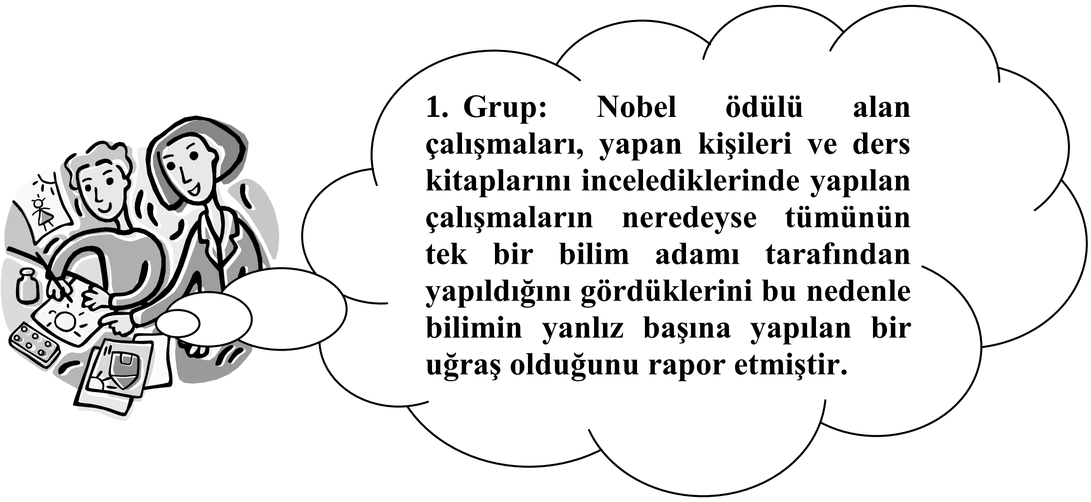


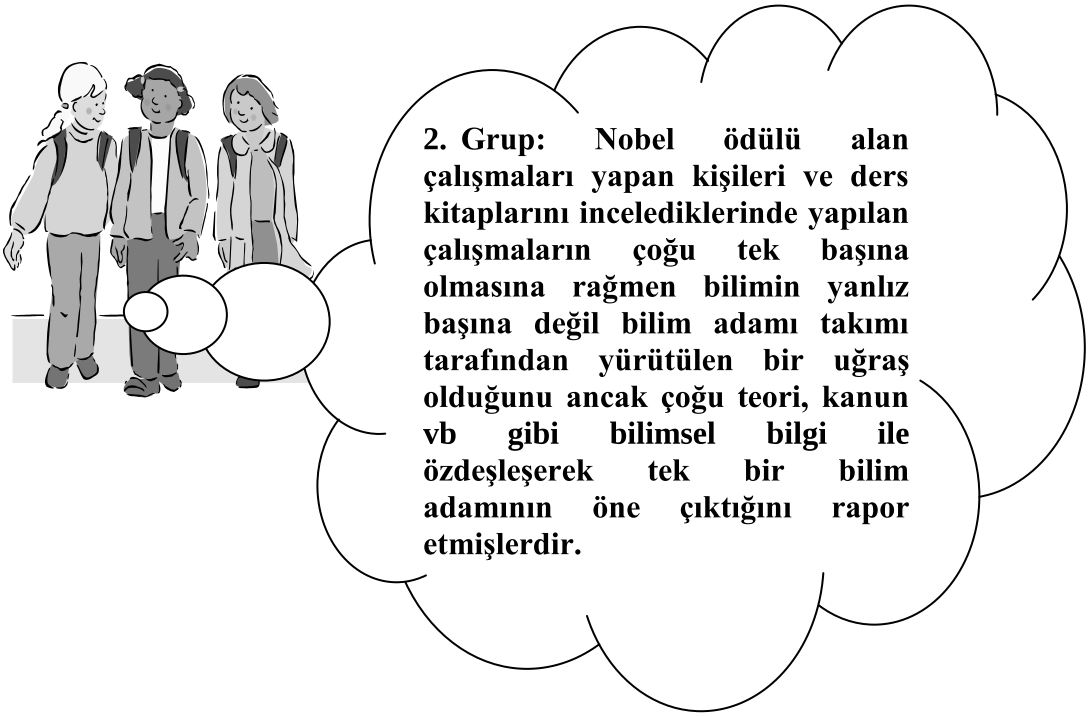
Bunun üzerine sınıftan diğer arkadaşları söz alarak bu konuda fikirlerini söylediler.



“Bilim yalnız başına yapılan bir uğraştır” miti ile ilgili karikatür

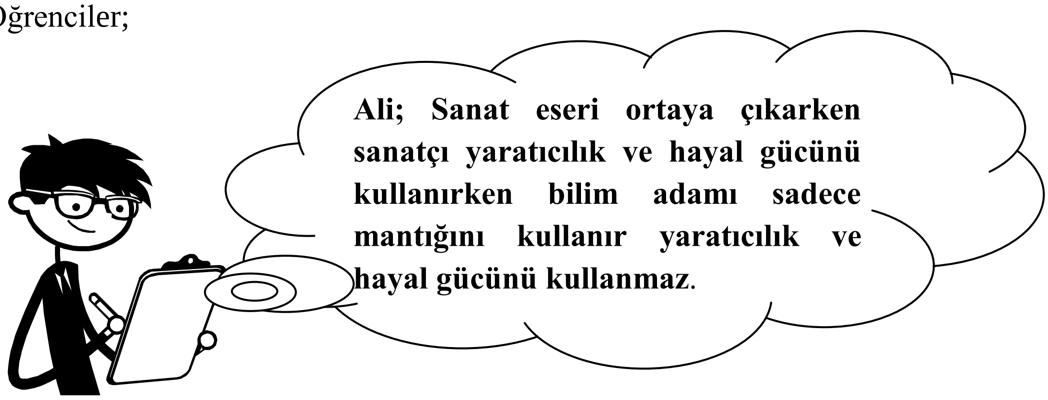
Öğretmen öğrencilerine kimya alanında Nobel Ödülü almış çalışmaları ve bu çalışmaları yapan kişileri araştırmalarını ve buun sonucunda bilim adamlarının nasıl çalıştıkları ile ilgili gruplar halinde bir rapor hazırlamalarını istemiştir.

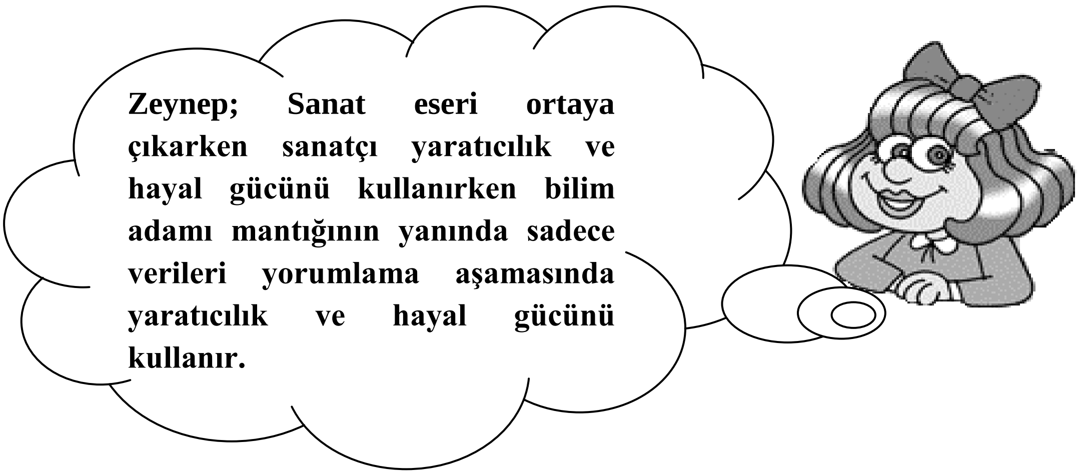


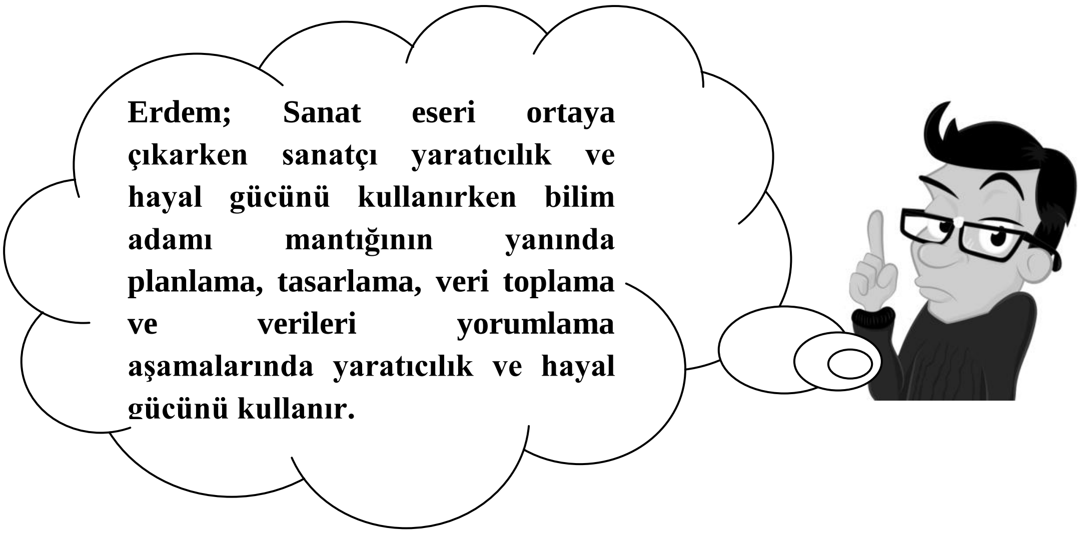


“Bilim yaratıcılıktan çok prosedür takip etmeyi gerektiren bir uğraştır” miti ile ilgili karikatür

Öğretmen öğrencilere bir sanat eserinin ortaya çıkma süreci ve bilimsel bir bilginin ortaya konulma sürecinde ne tür benzerlikler ve farklılıklar vardır? sorusunu sordu. Öğrenciler;







“Deney bilimsel bilgiye ulaşmak için olmazsa olmazdır” miti ile ilgili karikatür

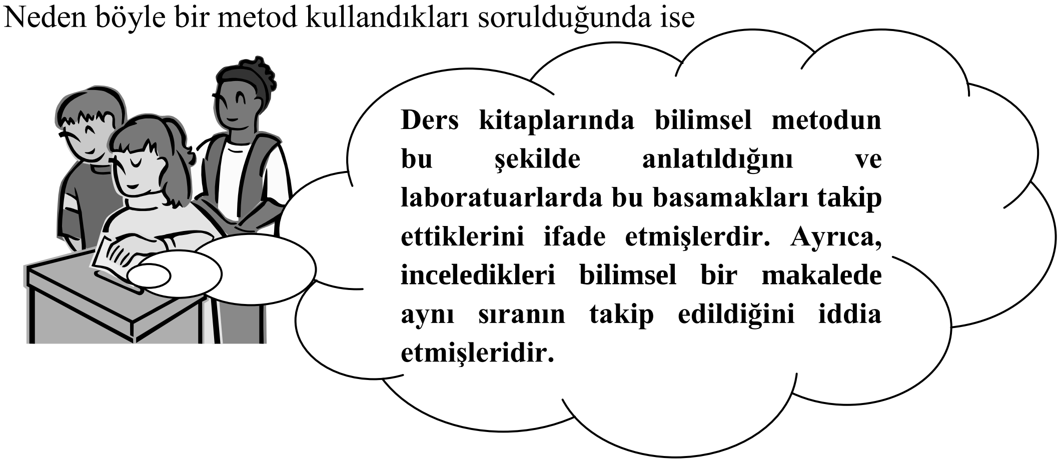
Furkan televizyonda bilimsel çalışmalar üzerine yayınlanan bir program izlediğini ve bu programdaki bir bilim adamının deney yapmadan sadece gözlem yaparak bilimsel bir kanun bulduğunu iddia ettiğini söyledi. Bu durumda sınıftaki diğer öğrenciler;

“Basamak basamak takip edilen genel ve evrensel bir bilimsel metod vardır” miti ile ilgili karikatür

Öğretmen gruplar halindeki öğrencilere bir araştırma sorusu vererek bu soruyu bilimsel metod kullanarak araştırmalarını ve kullandıkları metodu ve araştırma sonuçlarını rapor etmelerini istemiştir.

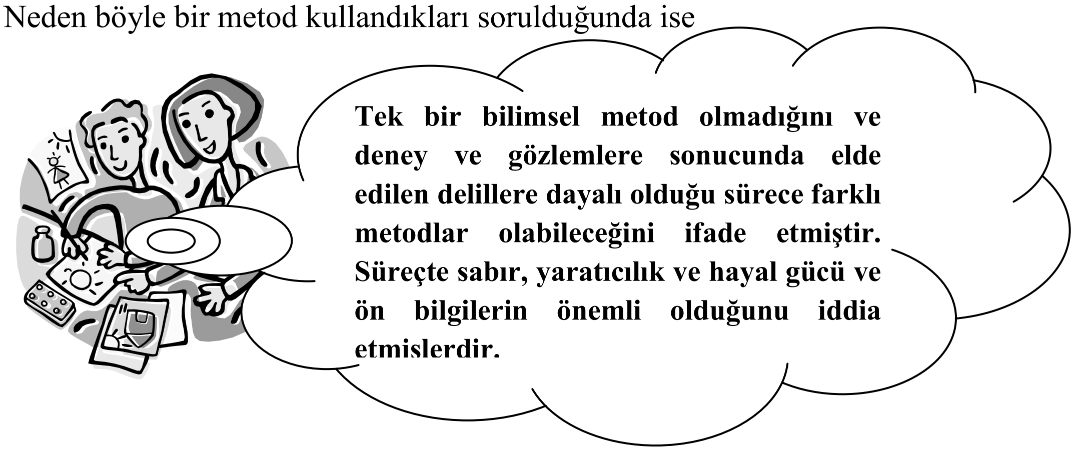
1. Grup; Verdikleri raporda aşağıdaki şekilde basamak basamak takip edilen bir metod izlediğini yazmıştır.
    a. Problemi tanımlamak
    b. Bilgi toplamak
    c. Hipotez kurmak
    d. Hipotezleri test etmek
    e. Teori ortaya atmak
    f. Sonuçları rapor etmek

Neden böyle bir metod kullandıkları sorulduğunda ise



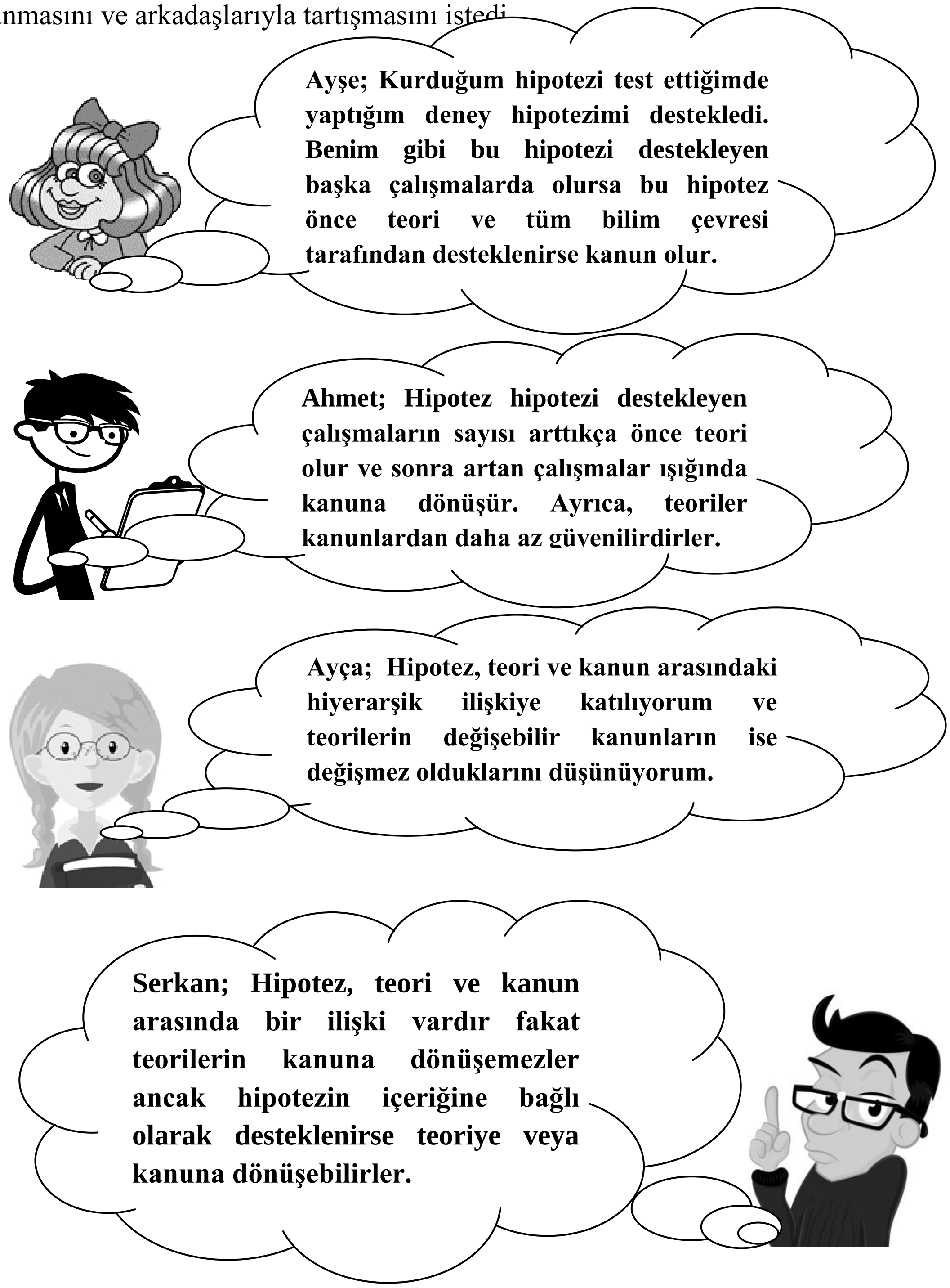
2. Grup; Verdikleri raporda aşağıdaki gibi bir metod izlediğini yazmıştır.
    a. Teori ortaya atmak
    b. Deneyler ve sonuçları
    c. Gözlemler ve sonuçları
    d. Sonuçları rapor etmek

Neden böyle bir metod kullandıkları sorulduğunda ise



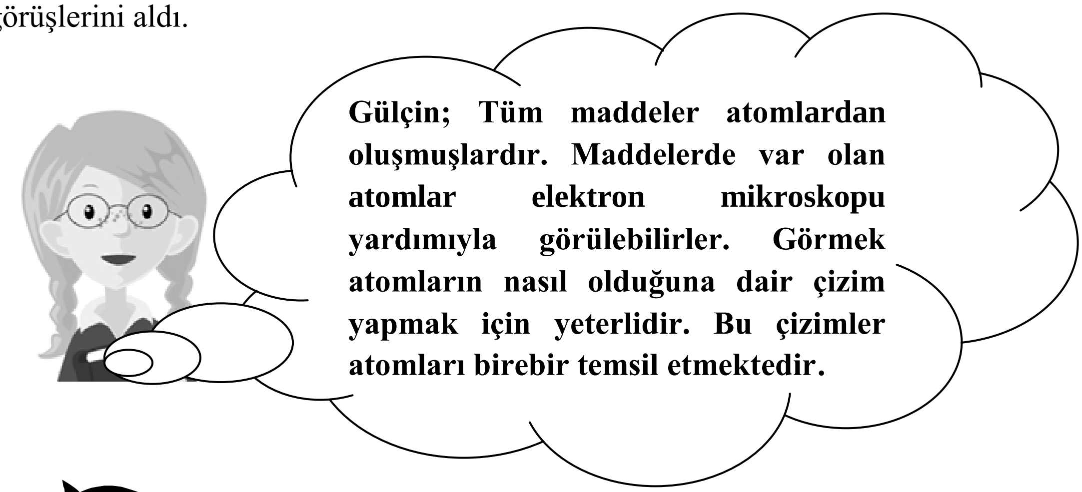
“Hipotezler once teori olurlar sonra kanun” miti ile ilgili karikatür

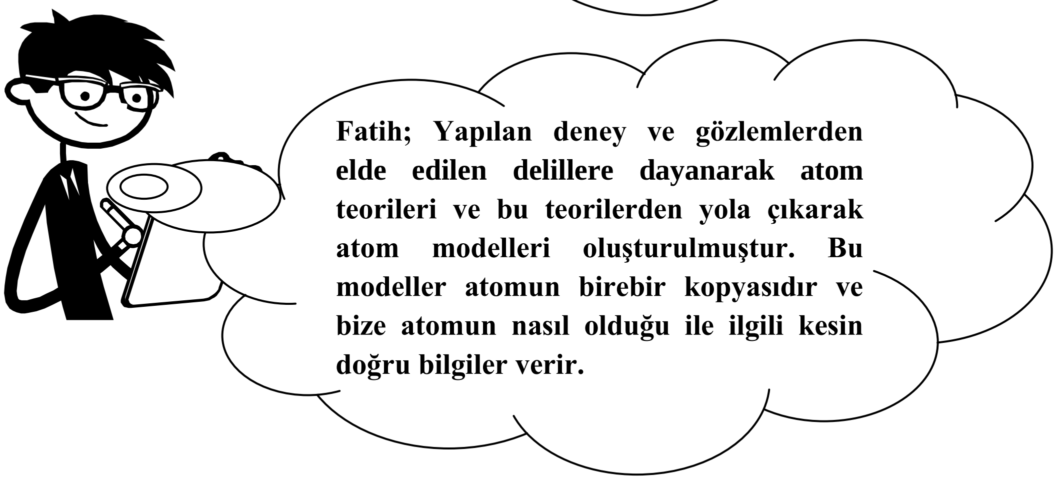
Öğretmen Ayşe’den bir hipotez kurmasını, kurduğu hipotezi (deney veya gözlem ile) test etmesini ve test ettikten sonra hipotezinin desteklenip desteklenmediğini sınıfa sunmasını ve arkadaşlarıyla tartışmasını istedi.

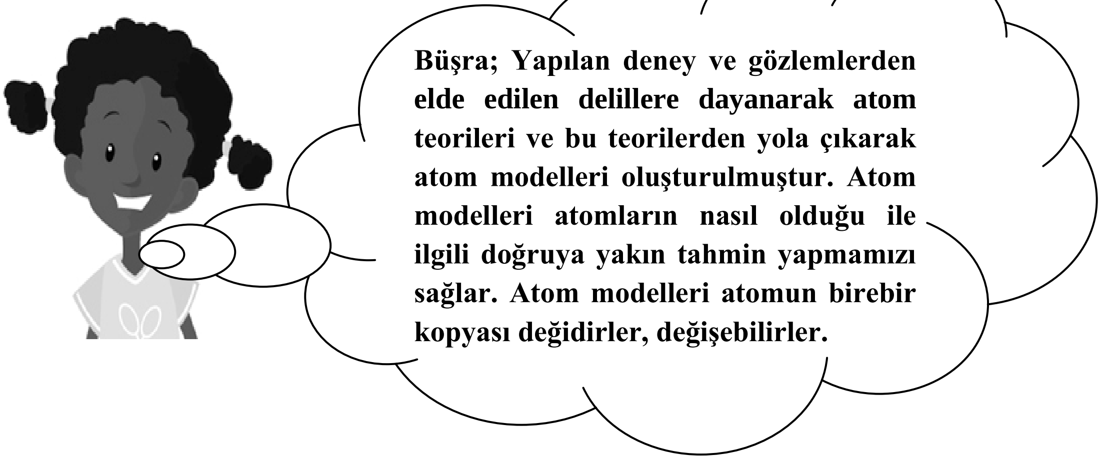


“Bilimsel modeler gerçeğin birebir kopyasıdır” miti ile ilgili karikatür

Aykut kardeşinin televizyonda bir atomun nasıl olduğu ile ilgili bir çizim gördüğünü ve bilim adamlarının bu çizimi nasıl yaptıklarını sorduğunu ve öğretmene kardeşine ne söylemesi gerektiğini sordu. Bunun üzerine öğretmen sınıftaki diğer öğrencilerin görüşlerini aldı.







Nasıl Yapılır?

Katılımcılar öğrencilerin bilimin doğası hakkındaki yanlış inanışları içeren kavram karikatürleri üzerinde argümantasyon sürecine dahil olmadan önce “Bir öğretmen adayı olarak, öğrencilerin zihinlerinde bilimin doğası hakkında var olan şeylerin neler olabileceğini düşünüyorsunuz?, Neden öğrencilerinizin zihninde bilimin doğası hakkında bir önceki cevapta bahsettiğiniz şeylerin olabileceğini düşünüyorsunuz? ve Bir başka deyişle, öğrenciler bilimin doğası hakkında zihinlerinde var olan şeyleri nerden öğrenmiş olabilirler?” sorularını cevaplarlar. Etkinlikten önce bilimin doğası hakkındaki mitleri göz önünde bulundurarak hazırlanan 11 adet kavram karikatürü zarflara konulur. Kavram karikatürleri aşağıda yer alan mitleri içermektedir.

- Hipotezler önce teori olur, ardından kanun.
- Bilimsel kanunlar ve bu tür diğer fikirler değişmez.
- Hipotez bilgiye/tecrübeye dayalı bir tahmindir.
- Genel ve evrensel bir bilimsel yöntem vardır.
- Dikkatlice toplanan kanıtlar kesin bilgilerle sonuçlanır.
- Bilim ve bilimin yöntemleri kesin kanıt sağlar.
- Bilim yaratıcılıktan çok bir prosedürdür.
- Bilim ve yöntemleri tüm sorulara cevap verebilir.
- Bilim insanları özellikle nesneldir.
- Deneyler bilimsel bilgiye ulaşmanın temel yollarıdır.
- Bilimsel sonuçlar doğruluğu açısından gözden geçirilir.
- Yeni bilimsel bilgiler hemen kabul edilir.
- Bilimsel modeller gerçeği gösterir.
- Bilim ve teknoloji aynı şeydir.
- Bilim yalnız yapılan bir uğraştır.

Katılımcılara hazırlanan zarfların bir öğretmenin sınıf içinde karşılaştığı durumlar olduğu ve çözümü için onların yardımına ihtiyaç duyduğu söylenir. Her grup 11 adet zarftan bir adet zarfı sırayla çeker ve daha sonra zarfı açarak grup halinde çalışırlar ve kavram karikatürleri üzerinde argümantasyon yaparak öğrencilerin bilimin doğası hakkında sahip oldukları inanışları fark ederler. Argümantasyon sürecinde kavram karikatüründeki hangi öğrencinin görüşüne neden katıldıkları, kendilerini karşı olan görüşleri nasıl ikna edebilecekleri, öğrencilerin bilimin doğası hakkındaki yanlış inanışlarının kaynaklarının neler olabileceği, bu yanlış inanışların yapacakları öğretimi nasıl etkileyeceği ve bu yanlış kavramları ortaya çıkarmak ve yok etmek için neler yapabilecekleri üzerinde dururlar. Tüm zarfların bitirilmesinden sonra bilimi doğası hakkındaki yanlış inanışların bilimin doğası öğretimini nasıl etkileyeceği üzerinde tartışma yürütülür. Sınıf tartışmasından sonra katılımcılar “Bu dersin vermek istediği mesaj nedir?, Fen öğretimi ile ilgili olarak bu derste neler öğrendiniz? ve Bu derste öğrendikleriniz bir öğretmen olarak fen eğitimine bakış açınızı özellikle bilimin doğası öğretiminde göz önünde bulundurmam gereken faktörler nelerdir sorusuna verdiğiniz cevapları nasıl değiştirmiştir?” sorularını cevaplayarak etkili bir bilimin doğası öğretimi için dikkat edilmesi gereken hususları tekrar gözden geçirme fırsatı bulurlar.

Çalışma Kağıdı

Grup Üyeleri:..

Biz__________________ 'nın görüşüne katılıyoruz.
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Bize karşı olan görüşler____

Bize karşı olan görüşleri____

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KNOWLEDGE of INSTRUCTIONAL STRATEGY CLASS

BİLİMİN DOĞASINI NASIL ÖĞRETEBİLİRİM?

BİLİMİN DOĞASI ÖĞRETİMİNDE KULLANILAN STRATEJİLER

Konu: Bilimin Doğası Öğretiminde Kullanılan Öğretme Stratejileri

Gereken Süre: 3 ders saati

Gerekçe:

Öğretmenlerin bilimin doğasını öğretebilmeleri için sadece bilimin doğası hakkında yeterli anlayışa sahip olmaları yeterli olmamakla birlikte, aynı zamanda bilimin doğasının öğretimi için pedagojik alan bilgisine sahip olmaları gerektiği vurgulanmaktadır. Pedagojik alan bilgisinin beş bileşenini tanımlayan bir modele göre bileşenlerden birini öğretmenlerin belli bir konuyu ve belli kavramları öğretmede kullanılabilecekleri öğretme stratejileri bilgisi oluşturmaktadır. Öğretmenlerin etkili bir öğretim tasarlayabilmesi kullandıkları öğretim stratejilerinin ne kadar etkili olduğu ile doğrudan ilgilidir. Öğretmenlerin bilimin doğası öğretmeme gerekçelerinden biride bilimin doğası öğretimi için zaman harcayarak fen kavramları öğretimi için yeterli zaman bulamamaktır. Bu nedenle bu etkinliğin amacı katılımcıların bilimin doğası öğretiminde kullanabilecekleri farklı öğretim stratejilerini ve bu stratejilerin fen kavramlarını öğretme sürecini olumsuz şekilde etkilemeyeceğini fark etmesini sağlamaktır.

Neye İhtiyaç Var?

- Biri açık-düşündürücü diğeri örtük yaklaşım kullanılarak hazırlanmış çözeltilerin kaynama noktası ve bilimin doğasını öğretmeyi amaçlayan iki adet ders planı
- Bilimin doğası öğretiminde kullanılabilecek stratejilerle ilgili slayt takımı
- Ders planları aşağıda verilmiştir.

Kolligatif Özellikler-Çözeltilerin Kaynama Noktası
(Ders Planı-1-Örtük Yaklaşım)

Öğretmen: Şimdiye kadar çözeltilerle ilgili temel kavramları (çözelti, çözünen, çözücü, çözelti türleri, çözünme, çözünme türleri-moleküler ve iyonik-) öğrenmiş olduk. Acaba çözeltilerin yoğunlukları, erime, kaynama noktaları gibi fiziksel özellikleri çözeltiyi oluşturan maddelerin fiziksel özellikleri ile karşılaştırıldığında nasıldır? Bugün sıvı çözeltilerin fiziksel özelliklerinden bir tanesi üzerinde duracağız. Sıvı çözeltilerin kaynama noktası çözeltiyi oluşturan saf çözücü ile karşılaştırıldığında nasıldır?

Öğretmen öğrencilerden gelen farklı cevapları ve gerekçelerini tahtaya yazar. Öğrencilerden gelen cevaplar;

- *Sıvı çözeltilerin kaynama noktası saf çözücüye göre daha yüksektir.*
    - *Çünkü çözeltide saf çözücüye göre daha fazla tanecikler arası etkileşim mevcuttur. Tanecikler arası etkileşimin artması kaynama noktasını yükseltir.*
- *Sıvı çözeltilerin kaynama noktası saf çözücüye göre daha düşüktür.*
    - *Çünkü çözücü taneciklerinin bir kısmı çözünen taneciklerinin etrafını sarar ve çözünen ile etkileşimde olmayan saf çözücü miktarı azalır. Bu nedenle az miktardaki çözücü daha düşük sıcaklıkta kaynar.*

Öğretmen: Şimdi sizden 4 kişilik gruplar oluşturmanızı ve grup arkadaşlarınızla iddialarınızı test edecek bir araştırma planlamanızı ve yürütmenizi istiyorum.

- Çözeltilerin kaynama noktası saf çözünen ve çözeltilerle karşılaştırıldığında değişir mi?
- Değişirse nasıl bir değişim olur (artar veya azalır)?
- Değişim çözünen ve/ya çözücü türüne bağlı mıdır?
- Çözelti kaynama noktasında değişim meydana geliyorsa bunun muhtemel açıklaması ne olabilir?

Araştırmanızı yaparken masanın üzerinde bulunan (su, etil alkol, tuz, termometre, ısı kaynağı, beher) malzemelerden istediğinizi kullanarak tasarladığınız araştırmayı yapmanızı ve en son olarak her grubun nasıl bir araştırma yaptığını anlatan bir poster hazırlayıp sunmasını istiyorum. Araştırmanızda her aşamayı niçin yaptığınızı açıklayınız ve gerekçelerini belirtiniz. Posterinizi hazırlarken aşağıda yer olan noktaları göz önünde bulundurmalısınız.

- Metodunuz
- Kullanılan malzemeler
- Elde edilen gözlem ve deney sonuçları
- Araştırmanızı yönlendiren soruların cevapları
- Yorumlarınız

Öğretmen öğrenciler deneylerini tasarlarken sınıf içerisinde dolaşır ve öğrencilerin nasıl bir süreç yaşadıklarını gözlemler. Bu süreçte öğrencilerin zorluk yaşadığı noktalarda onlara yönlendirici sorular sorarak araştırmalarını tasarlamarı konusunda ilerlemelerine yardımcı olur. Tüm sınıf araştırmasını tamamladıktan sonra her bir grup kendi posterini sunar. Sunma sürecinde diğer gruplar sunum yapan gruba araştırmaları ile ilgili soru sorabilirler. Öğretmenin rehberliğinde yürütülen bu süreç sonunda öğretmen öğrencilerin ***"Bir sıvıda kendinden daha az uçucu bir katı çözündüğünde kaynama noktası artarken kendinden daha uçucu bir sıvı çözündüğünde kaynama noktası düşer"*** *sonucuna ulaşmalarını ve bu sonuca paralel olarak* ***tanecikleri arası etkileşim kavramını*** *kullanarak (bir önceki derste çözünme ve çözünme türleri tanecik ve tanecikler arası etkileşim kavramı kullanılarak anlatılığı için)* ***uygun açıklamaları*** *yapmalarını bekler.*

<u>Öğretmen:</u> Şimdi sizden bugün öğrendiğiniz kavramları ve bir önceki derste öğrendiğiniz kavramları dikkate alarak bir kavram haritası oluşturmanızı istiyorum. Haritada yer alacak kavramların seçimini size bırakıyorum.

Öğretmen dersin sonunda öğrencilere kendi kavram haritalarını oluşturmaları için fırsat vererek öğrencilerin anlamlı bir şekilde öğrenip öğrenmediklerini ve yaptığı öğretimin etkili olup olmadığını anlama fırsatı bulur. Kavram haritalarını tamamladıktan sonra dersin sonunda öğrencilere bir sonraki ders için üzerinde düşünmeleri gereken bir araştırma sorusu ödevi verir.

> **<u>Öğretmen</u>**: Kaynama noktası yükselmesi sıvı çözücüde çözünen ve uçucu olmayan maddenin türüne bağlı mıdır? Bunu nasıl belirlersiniz? Belirlemek için bir araştırma planı hazırlayın. Bir sonraki derste size planladığınız bu araştırmayı gerçekleştirmek için fırsat vereceğim.

Kolligatif Özellikler-Çözeltilerin Kaynama Noktası
(Ders Planı-2-Açık Düşündürücü Yaklaşım)

Öğretmen: Şimdiye kadar çözeltilerle ilgili temel kavramları (çözelti, çözünen, çözücü, çözelti türleri, çözünme, çözünme türleri-moleküler ve iyonik-) öğrenmiş olduk. Acaba çözeltilerin yoğunlukları, erime, kaynama noktaları gibi fiziksel özellikleri çözeltiyi oluşturan maddelerin fiziksel özellikleri ile karşılaştırıldığında nasıldır? Bugün sıvı çözeltilerin fiziksel özelliklerinden bir tanesi üzerinde duracağız. Sıvı çözeltilerin kaynama noktası çözeltiyi oluşturan saf çözücü ile karşılaştırıldığında nasıldır?

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Araştırmanızı yaparken masanın üzerinde bulunan (su, etil alkol, tuz, termometre, ısı kaynağı, beher) malzemelerden istediğinizi kullanarak tasarladığınız araştırmayı yapmanızı ve en son olarak her grubun nasıl bir araştırma yaptığını anlatan bir poster hazırlayıp sunmasını istiyorum. Araştırmanızda her aşamayı niçin yaptığınızı açıklayınız ve gerekçelerini belirtiniz. Posterinizi hazırlarken aşağıda yer olan noktaları göz önünde bulundurmalısınız.

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Öğretmenin rehberliğinde yürütülen bu süreç sonunda öğretmen öğrencilerin ***"Bir sıvıda kendinden daha az uçucu bir katı çözündüğünde kaynama noktası artarken kendinden daha uçucu bir sıvı çözündüğünde kaynama noktası düşer"*** *sonucuna ulaşmalarını ve bu sonuca paralel olarak* ***tanecikleri arası etkileşim kavramını kullanarak*** *(bir önceki derste çözünme ve çözünme türleri tanecik ve tanecikler arası etkileşim kavramı kullanılarak anlatılığı için)* ***uygun açıklamaları yapmalarını*** *bekler.*

Gruplar poster sunumlarını yaparlarken ve/ya yaptıktan sonra öğretmen gruplara aşağıda yer alan soruları yöneltir ve bir sınıf tartışması yürütür.

- *Araştırmanızı nasıl yürüttünüz? Araştırmanız süresince belirli basamaklar takip ettiniz mi? Bu süreçte tüm grupların aynı basamakları takip etmesi gerekir mi? Diğer gruplar araştırmalarını farklı şekillerde yürütebilirler mi? Eğer cevabınız evet ise diğer gruplar kullandıkları yöntem hakkında sizi nasıl ikna edebilirler? Cevabınızı nedenleri ile birlikte açıklayınız.*
- *Çözeltilerin kaynama noktalarının saf çözücü ve çözünen ile karşılaştırıldıkları zaman nasıl değiştiğine dair açıklamalarınıza sadece deney ve/ya gözlem yaparak mı ulaştınız? Cevabınız hayır ise gözlem ve/ya deney dışında bu süreçte neler yaptınız?*

- *Çözeltilerin kaynama noktalarının saf çözücü ve çözünen ile karşılaştırıldıkları zaman nasıl değiştiğine dair açıklamalarınız hakkında nasıl bu kadar emin olabiliyorsunuz? Açıklamalarınız için delilleriniz nelerdir? Gelecekte açıklamalarınız değişir mi? Cevabınızı nedenleri ile birlikte açıklayınız.*
- *Kaynama noktasındaki yükselmenin ve düşmenin nasıl meydana geldiği ile ilgili biri yükselme biri düşme için olmak üzere ikiden fazla açıklama olabilir mi? Bu açıklamalardan hangisine inanacağınıza nasıl karar verirsiniz? Kaynama noktasındaki yükselmenin ve düşmenin ileri sürülen açıklamalardan hangisi ile birebir örtüştüğünü test edebilir misiniz? Cevabınızı nedenleri ile birlikte açıklayınız.*

Öğretmen sınıf tartışmasını tamamladıktan sonra öğrencilere kendi kavram haritalarını oluşturmaları için fırsat vererek öğrencilerin anlamlı bir şekilde öğrenip öğrenmediklerini ve yaptığı öğretimin etkili olup olmadığını anlama fırsatı bulur.

Öğretmen: Şimdi sizden bugün öğrendiğiniz kavramları ve bir önceki derste öğrendiğiniz kavramları dikkate alarak bir kavram haritası oluşturmanızı istiyorum. Haritada yer alacak kavramların seçimini size bırakıyorum.

Kavram haritalarını tamamladıktan sonra dersin sonunda öğrencilere bir sonraki ders için üzerinde düşünmeleri gereken bir araştırma sorusu ödevi verir.

Öğretmen: Kaynama noktası yükselmesi sıvı çözücüde çözünen ve uçucu olmayan maddenin türüne bağlı mıdır? Bunu nasıl belirlersiniz? Belirlemek için bir araştırma planı hazırlayın. Bir sonraki derste size planladığınız bu araştırmayı gerçekleştirmek için fırsat vereceğim.

Nasıl Yapılır?

Katılımcılar bilimin doğasını çözeltilerin kaynama noktasına entegre olmuş şekilde öğretmek amacıyla iki farklı yaklaşımla hazırlanmış ders planlarını incelemeden önce katılımcıların var olan öğretim stratejileri bilgilerini ortaya çıkarmak amacı ile "Öğrencilerinize kimya kavramları yanında bilimin doğasını da öğretmeyi planladığınız bir derste nasıl bir öğretim yöntemi uygularsınız?" sorularını cevaplarlar. Bu soruyu cevapladıktan sonra "Çözeltilerin kaynama noktası" konusunda örtük ve açık-düşündürücü yaklaşımla hazırlanmış hem konu alanını, hem de bilimin doğası ile ilgili belirli kazanımlara ulaştığını iddia eden iki ders planı katılımcılara verilir ve katılımcılar gruplar halinde ders planlarını hedeflenen kazanımlar, kullanılan öğretim yaklaşımları ve kullanılan öğretim yaklaşımının hedeflenen kazanımlar açısından uygunluğu ve etkililiği açısından değerlendirirler. Her grup değerlendirmelerini tamamlayıp sınıfla paylaşırlar. Daha sonra "Öğrencilerimin hem kimya kavramlarını hem de bilimin doğasını öğrenebilecekleri bir öğretim dizayn etmek istiyorum. Ancak aynı ders saati içerisinde hem kimyayı hem de bilimin doğasını nasıl öğretebilirim?" problemi ile karşı karşıya olan bir öğretmenin kendilerinden yardım istediği belirtilir. İki fen eğitimi uzmanının ders planlarında kullanılan yaklaşımlarla ilgili argümanlarını içeren kavram karikatürleri öğretmen adaylarına verilerek katılımcıların argümantasyon sürecine dahil olmaları sağlanır.

- **Argüman 1:** Öğrencilerinizin bilimsel bir sorgulayıcı-araştırma (inquiry) sürecini sadece yaşamaları veya derslerinizde bilim tarihi üzerinde durmanız öğrencilerinizin hem kimya kavramlarını hemde bilimin doğasını öğrenmesini sağlar. Böylece öğrencileriniz doğrudan kimyayı ve örtük (dolaylı) bir şekilde bilimin doğasını öğrenmiş olurlar. Bilimin doğasını anlama motivasyon, tutum vb. gibi özel olarak odaklanmasanız bile ulaşabilceğiniz duyuşsal bir kazanımdır. Bilimin doğasını öğrenme süreç içinde kendiliğinden gerçekleşir.
- **Argüman 2:** Bilimin doğası motivasyon, tutum gibi ders süresince özellikle odaklanmasanız bile kendiliğinden ulaşılabilecek bir kazanım değildir. Bilimin doğasını anlama bilişsel bir öğrenme kazanımıdır ve kendiliğinden gelişmesi beklenemez. Öğrencilerinizin bilimin doğasını öğrenmelerini istiyorsanız kimya kazanımları yanında bilimin doğası için kazanımlarınızı yazarak öğretimi bu yönde dizayn etmelisiniz. Bilimin doğası öğrencilerin ders sürecinde yapılan etkinlikler ile bilim arasında açık bir şekilde derinlemesine düşünmelerini sağlayarak öğretilebilir. Öğrencilere, sürekli olarak yaşadıkları öğrenme deneyimlerini bilimin doğası açısından sorgulama, kendi deneyimleri ile bilim insanlarının çalışmaları, bilimin işleyişi ve bilimsel bilginin özellikleri arasında bağlantı kurma ve genellemeler yapma fırsatları verilmelidir. Böyle bir süreçte bilimin doğası

kimya öğretimine entegre edilmiş olur ve öğrenciler hem kimyayı hem de bilimin doğasını anlamlı bir şekilde öğrenmiş olurlar. Bilimin doğasını öğretmek için normal ders saati dışında ekstra bir ders saati gerektirmez.

Her bir grup hangi fen eğitim uzmanının görüşüne neden katıldığını ve diğerine neden katılmadığını gerekçeleri ile birlikte sınıfla paylaşır. Daha sonra bilimin doğası öğretiminde kullanılan öğrenme stratejileri ile ilgili bir sunum yapılır ve bilimin doğasını öğretmek için ekstra bir zamana ya da yeni bir öğretim stratejisini öğrenmeye ihtiyaç duymadıkları vurgulanır. Öğretim stratejileri hakkında sunum yapılırken katılımcılardan bilimin doğasını öğrenme aşamasında tecrübe ettikleri stratejilere örnek vermeleri ve bu stratejilerle bilimin doğasının hangi boyutlarını öğretebileceklerini anlatmaları istenir. Sunumdan sonra katılımcılar "Bu dersin vermek istediği mesaj nedir?, Fen öğretimi ile ilgili olarak bu derste neler öğrendiniz?, Bu derste öğrendikleriniz bir öğretmen olarak fen eğitimine bakış açınızı özellikle neden fen öğretiyorum sorusuna verdiğiniz cevapları nasıl değiştirmiştir? ve Bu derste öğrendikleriniz yapacağınız fen öğretiminizi özellikle bilimin doğasını öğretme amacıyla öğretimi dizayn etme sürecinizi nasıl etkiler?" sorularını cevaplayarak bilimin doğasının öğretiminde kullanabilecekleri öğretim stratejileri bilgilerini tekrar gözden geçirme fırsatı bulurlar.

Çalışma Kağıdı 1

Ders Planı Analizi

Grup Üyeleri:...

DERS PLANI-1	DERS PLANI-2
KAZANIMLAR	**KAZANIMLAR**
ÖĞRETİM METODU	**ÖĞRETİM METODU**
METODUN ULAŞILMAK İSTENEN KAZANIMLAR AÇISINDAN UYGUNLUĞU	**METODUN ULAŞILMAK İSTENEN KAZANIMLAR AÇISINDAN UYGUNLUĞU**

Çalışma Kağıdı 2

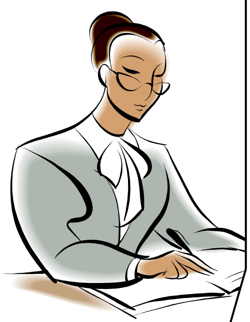
Grup Üyeleri:...

Öğrencilerimin hem kimya kavramlarını
hem de bilimin doğasını öğrenebilecekleri
bir öğretim dizayn etmek istiyorum. Ancak
aynı ders saati içerisinde hem kimyayı hem
de bilimin doğasını nasıl öğretebilirim?

Fen eğitimi uzmanı Mehmet Bey (Ders Planı 1)

Öğrencilerinizin bilimsel bir sorgulayıcı-araştırma (inquiry) sürecini sadece yaşamaları veya derslerinizde bilim tarihi üzerinde durmanız öğrencilerinizin hem kimya kavramlarını hemde bilimin doğasını öğrenmesini sağlar. Böylece öğrencileriniz doğrudan kimyayı ve örtük (dolaylı) bir şekilde bilimin doğasını öğrenmiş olurlar. Derslerinizde kimya kazanımları dışında bilimin doğası için de ayrıca kazanım yazıp öğretimi bu yönde dizayn etmenize gerek yoktur. Bilimin doğasını anlama motivasyon, tutum vb. gibi özel olarak odaklanmasanız bile ulaşabilceğiniz duyuşsal bir kazanımdır. Bilimin doğasını öğrenme süreç içinde kendiliğinden gerçekleşir.

Fen eğitimi uzmanı Ayşe Hanım (Ders Planı 2)



Bilimin doğası motivasyon, tutum gibi ders süresince özellikle odaklanmasanız bile kendiliğinden ulaşılabilecek bir kazanım değildir. Bilimin doğasını anlama bilişsel bir öğrenme kazanımıdır ve kendiliğinden gelişmesi beklenemez. Öğrencilerinizin bilimin doğasını öğrenmelerini istiyorsanız kimya kazanımları yanında bilimin doğası için kazanımlarınızı yazarak öğretimi bu yönde dizayn etmelisiniz. Bilimin doğası öğrencilerin ders sürecinde yapılan aktiviteler ile bilim arasında açık bir şekilde derinlemesine düşünmelerini sağlayarak öğretilebilir. Öğrencilere, sürekli olarak yaşadıkları öğrenme deneyimlerini bilimin doğası açısından sorgulama, kendi deneyimleri ile bilim insanlarının çalışmaları, bilimin işleyişi ve bilimsel bilginin özellikleri arasında bağlantı kurma ve genellemeler yapma fırsatları verilmelidir. Böyle bir süreçte bilimin doğası kimya öğretimine entegre edilmiş olur ve öğrenciler hem kimyayı hem de bilimin doğasını anlamlı bir şekilde öğrenmiş olurlar. Bilimin doğasını öğretmek için normal ders saati dışında ekstra bir ders saati gerektirmez.

Biz fen eğitimcisi______________________________________ görüşüne katılıyoruz. Çünkü____

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Bize karşı olan görüş____

Bize karşı olan görüşü____

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KNOWLEDGE of ASSESSMENT CLASS

BİLİMİN DOĞASINI NASIL DEĞERLENDİREBİLİRİM?: DEĞERLENDİRİLME SÜRECİNDE KULLANILACAK ÖLÇME VE DEĞERLENDİRME TEKNİKLERİ

Konu: Bilimin Doğası Değerlendirme Sürecinde Kullanılan Ölçme ve Değerlendirme Teknikleri

Gereken Süre: 3 ders saati

Gerekçe:

Öğretmenlerin bilimin doğasını öğretebilmeleri için sadece bilimin doğası hakkında yeterli anlayışa sahip olmalarının yeterli olmamakla birlikte, aynı zamanda bilimin doğasının öğretimi için pedagojik alan bilgisine sahip olmaları gerektiğini vurgulanmaktadır. Pedagojik alan bilgisinin beş bileşenini tanımlayan bir modele göre bileşenlerden birini öğretmenlerin belli bir konuyu ve belli kavramları değerlendirmek amacıyla kullanılabilecekleri ölçme ve değerlendirme bilgisi oluşturmaktadır. Ölçme ve değerlendirme bilgisi öğrencilerin var olan bilgilerini ortaya çıkarmak ve öğretim sürecininin etkililiğini belirlemek amacıyla kullanılarak öğretimi nasıl tasarlayabilecekleri veya ileriye dönük olarak nasıl revize edebilecekleri konusunda öğretmene geri dönüt sağlar. Yapılan araştırmalar öğretmenlerin bilimin doğası öğretiminde kullanılacak ölçme ve değerlendirme bilgilerinin çok az veya gelişmemiş olduğunu göstermektedir. Bu nedenle bu etkinliğin amacı katılımcıların bilimin doğasını öğretmeyi hedefledikleri bir derste ölçme ve değerlendirme sürecine de dahil etmeleri gerektiği ve dahil ettikleri durumda ne tür teknikler kullanabileceklerini fark etmelerini sağlamaktır.

Neye İhtiyaç Var?

- Bilimin doğası ve temel fen kavramları öğretimini amaçlayan bir ders planına ait kazanımlar
- Değerlendirme sürecinde sorunlar yaşayan bir öğretmenle ilgili problem durumu

- Bilimin doğasın ölçme ve değerlendirme teknikleri üzerine hazırlanmış bir slay takımı

Nasıl Yapılır?

Katılımcılar "Bilimin Doğasını Nasıl Öğretebilirim?" konulu haftada bilimin doğası öğretiminde kullanılan örtük ve açık düşündürücü yaklaşımla hazırlanmış ders planlarını inceledikleri için bu derste onlara daha önce inceledikleri ders planına ait olan kazanımlar verilir. Kazanımlar aşağıdaki gibidir;

Genel kazanımlar:

Bu dersin sonunda öğrenciler;

- Sıvı çözeltilerin kaynama noktalarının çözünen türüne göre nasıl değişeceğini kendi cümleleri ile ifade eder.
- Bilimsel bilginin elde edilme ve kabul edilme sürecini kendi cümleleri ile ifade eder.

Özel kazanımlar:

Bu dersin sonunda öğrenciler;

- Bir sıvıda çözünen çözücü türüne göre kaynama noktası değişimini gösteren bir deney tasarlar.
- Bir sıvıda kendinden daha az uçucu bir katı çözündüğünde kaynama noktası yükselmesinin sebebini açıklar.
- Bir sıvıda kendinden daha uçucu bir sıvı çözündüğünde kaynama noktası düşmesinin sebebini açıklar.
- Gözlem ve çıkarım arasındaki farkı ve bilimdeki yerini anlar.
- Bilimsel bilginin deney ve gözlem sonucu elde edilen delillere dayandığını anlar.
- Adım adım takip edilen genel ve evrensel bilimsel bir yöntem olmadığını anlar.

İncelenen kazanımlar daha önce bilinen ders planları ile ilgili olmak zorunda değildir. Alternatif olarak bilimin doğası öğretimine yönelik yeni ders planları ve bu planlara ait kazanımlar katılımcılara verilebilir. Katılımcılara "Öğrencilerin hem belirlediğim kazanımlara ulaşıp ulaşmadıklarını hem de kazanımlara ulaşma açısından yaptığım öğretimin etkili olup olmadığını belirlemek istiyorum. Nasıl bir ölçme ve değerlendirme yapmalıyım?" konusunda bir öğretmenin kendilerinden yardım istediği ve gruplar halinde çalışarak bu öğretmenin problemini çözmek için spesifik olarak ölçme ve değerlendirme örnekleri hazırlamaları söylenir. Burada amaç katılımcıların bilimin doğasını ölçme ve değerlendirmeye dahil edip etmeyeceklerini ve dahil ederlerse ne tür ölçme ve değerlendirme teknikleri kullanmayı tercih edeceklerini ortaya çıkarmaktır. Her grup önerdikleri ölçme ve değerlendirme örneklerini sınıfla paylaştıktan sonra araştırmacı tarafından problem yaşayan öğretmene yardım amacı ile hazırlanan ölçme ve değerlendirme örnekleri paylaşılır. Katılımcıların önerilen ölçme ve değerlendirme teknikleri üzerinde görüşleri alınır ve bilimin doğasına yönelik ölçme ve değerlendirme sürecinde kullanılabilecek teknikler ile ilgili bir sunum yapılır. Sunumdan sonra katılımcılar "Bu dersin vermek istediği mesaj nedir?, Fen öğretimi ile ilgili olarak bu derste neler öğrendiniz?, Bu derste öğrendikleriniz bir öğretmen olarak fen eğitimine bakış açınızı özellikle bilimin doğasını öğrettiğiniz derste ölçme ve değerlendirmeyi nasıl yapmalıyım sorusuna verdiğiniz cevapları nasıl değiştirmiştir? ve Bu derste öğrendikleriniz yapacağınız fen öğretiminizi özellikle bilimin doğasını öğretme amacıyla öğretimi dizayn etme sürecinizi nasıl etkiler?" sorularını cevaplayarak bilimin doğasının değerlendirilmesinde kullanabilecekleri ölçme ve değerlendirme bilgilerini tekrar gözden geçirme fırsatı bulurlar.

Çalışma Kağıdı

Grup Üyeleri:...

Öğrencilerin hem belirlediğim kazanımlara ulaşıp ulaşmadıklarını hem de kazanımlara ulaşma açısından yaptığım öğretimin etkili olup olmadığını belirlemek istiyorum. Nasıl bir ölçme ve değerlendirme yapmalıyım?

APPENDIX D

VIEWS of the NATURE of SCIENCE QUESTIONNAIRE (VNOS C)

Bilimin Doğası Hakkında Görüşler Anketi (Türkçe)

1. Bilim ne demektir? Bilimi (veya fizik, biyoloji gibi bir bilimsel alanı) diğer araştırma alanlarından (örneğin, din ve felsefe) farklı kılan şey nedir?

2. Deney ne demektir?

3. Bilimsel bilginin gelişmesi için deney gerekli midir?

 Evetse, niçin? Görüşünüzü destekleyen bir örnek veriniz.

 Hayırsa, niçin? Görüşünüzü desteleyen bir örnek veriniz.

4. Bilim insanları bilimsel bir teori geliştirdikten sonra (örneğin atom teorisi, evrim teorisi) bu teori hiç değişir mi?

 Eğer bilimsel teorilerin değişmeyeceğine inanıyorsanız nedenini açıklayınız? Cevabınızı örneklerle destekleyiniz.

 Eğer bilimsel teorilerin değişeceğine inanıyorsanız, (a) teorilerin niçin değiştiğini açıklayınız (b) o zaman niçin teorileri öğrenmek için çaba harcadığımızı açıklayınız. Cevabınızı örneklerle destekleyiniz.

5. Bilimsel teori ve bilimsel kanun arasında fark var mıdır? Bir örnek veriniz.

6. Fen kitapları genellikle atomun; protonlar (pozitif yüklü parçacıklar) ve nötronların (nötr parçacıklar) bulunduğu merkezdeki bir çekirdek ile çekirdek etrafında dolaşan elektronlardan (negatif yüklü parçacıklar) oluştuğunu ifade eder. Bilim insanları atomun yapısı hakkında nasıl bu kadar emin olabilmektedirler? Bilim insanlarının atomun neye benzediğine karar verirken hangi spesifik delilleri kullandıklarını düşünüyorsunuz?

7. Fen kitapları bir türü, genellikle benzer özelliklere sahip organizmaların oluşturduğu ve verimli döller üretmek için birbirleriyle çiftleşen grup olarak

tanımlar. Bilim insanları bir türün ne olduğuyla ilgili özellikler hakkında nasıl emin olmaktadırlar? Bilim insanlarının bir türün ne olduğunu belirlemek için hangi spesifik delilleri kullandıklarını düşünüyorsunuz?

8. Yaklaşık 65 milyon yıl önce dinozorların yok olduğuna inanılmaktadır. Bilim insanları tarafından bu yok oluşu açıklamak için oluşturulan hipotezlerden ikisi daha fazla kabul edilmektedir. Bir grup bilim insanı tarafından oluşturulan birinci hipotez; 65 milyon yıl önce kocaman bir meteorun dünyaya çarptığını ve yok oluşa neden olan bir dizi olaya yol açtığını öne sürer. Diğer bir grup bilim insanı tarafından oluşturulan ikinci hipotez ise; büyük ve şiddetli bir volkanik patlamanın bu yok oluşa neden olduğunu öne sürer. Eğer her iki gruptaki bilim insanları aynı verilere ulaşıyor ve aynı verileri kullanıyorlarsa, bu farklı sonuçlar nasıl ortaya çıkmaktadır?

9. Bazı insanlar, bilimin sosyal ve kültürel değerlerden etkilendiğini iddia etmektedir. Yani, bilim sosyal ve politik değerleri, felsefi varsayımları ve üretildiği kültürün akla uygun normlarını yansıtmaktadır. Diğerleri ise, bilimin evrensel olduğunu iddia etmektedir. Yani, bilim ulusal ve kültürel sınırları aşmaktadır ve sosyal, politik ve felsefi değerlerden ve üretildiği kültürün akla uygun normlarından etkilenmemektedir.

- Eğer bilimin sosyal ve kültürel değerleri yansıttığına inanıyorsanız, nedenini açıklayınız. Cevabınızı örneklerle destekleyiniz.

- Eğer bilimin evrensel olduğuna inanıyorsanız, nedenini açıklayınız. Cevabınızı örneklerle destekleyiniz.

10. Bilim insanları, ileri sürdükleri sorulara cevap bulmaya çalışırken deneyler ve araştırmalar yapmaktadır. Bilim insanları bu araştırmaları boyunca yaratıcılıklarını ve hayâl güçlerini kullanmakta mıdır?

- Cevabınız evetse, araştırmanın hangi aşamasında - planlama ve tasarlama, veri toplama, veri topladıktan sonra - bilim insanlarının hayâl güçlerini ve yaratıcılıklarını kullandıklarını düşünüyorsunuz? Bilim insanlarının neden hayâl güçlerini ve yaratıcılıklarını kullandıklarını açıklayınız. Mümkünse örnekler veriniz.

- Eğer bilim insanlarının hayâl güçlerini ve yaratıcılıklarını kullanmadıklarını düşünüyorsanız, nedenini açıklayınız. Mümkünse örnekler veriniz.

APPENDIX E

LESSON PLAN FORMAT

RAPOR

- Tarihsel Gelişim
- Yanlış Kavramlar
- Günlük yaşam uygulamaları

GÜNLÜK DERS PLANI

1. **Konu:**

2. **Zamanlama:** Öğretim sürecini nasıl kullanacaksınız? Planınızı yazınız.

3. **Önkoşul Kazanımlar:** Bu dersten önce öğrencilerin sahip olması gereken bilgiler nelerdir?

4. **Genel Kazanımlar:** Sayısı maximum 4 olmalı

5. **Özel Kazanımlar:**

6. **Öğretim Materyalleri (Grafik, Resim, Karikatür, Poster, Film, Slayt, Maket), teknoloji, ve medya:** Ne tür öğretime yardımcı materyaller kullanacaksınız?

7. **Öğretim Stratejisi:** Kullanacağınız öğretim stratejisini yazın ve strateji hakkında bilgi verin.

8. **Ön ödevler:** Konuyu etkili bir şekilde öğrenmeleri için öğrecilerinize ne tür ödevler (okuma veya çalışma) verirsiniz?

9. **Son ödevler:** Öğrencilerinizin konuyu etkili bir şekilde pekiştirmeleri için ne tür ödevler verirsiniz?

10. **Öğretmen hazırlığı:** Öğretmen ders için ne tür hazırlıklar yapar?

11. **Öğretim materyalleri, öğretim stratejisi ve kazanımlarla entegre edilmiş halde konunun sunulması:**
    - Konunun teorisi ile birlikte adım adım nasıl bir öğretim yapılacak?
    - Kazanımlarınıza ders sürecinde nasıl ulaşacaksınız?
    - Ders sürecinde öğretim materyallerini nasıl ve ne zaman kullanacaksınız?
    - Seçtiğiniz öğretim stratejisini nasıl uygulayacaksınız?

    Bu aşamada hazırladığınız dersin detaylı bir planının olması beklenmektedir. Sınıfa girdiğiniz andan itibaren söyleyeceğiniz ve yapacağınız herşeyi yazmanız gerekmektedir. Planın bu kısmında stratejiyi nasıl uyguladığınızı, materyalleri nasıl kullandığınızı ve kazanımlarınıza nerde ve nasıl ulaştığınızı açık bir şekilde anlatmanız beklenmektedir.

12. **Değerlendirme:** Öğrencilerinizi ders sürecinde ve/ya ders sonunda nasıl değerlendireceksiniz?

13. **Kaynaklar:**

APPENDIX F

INTERVIEW QUESTIONS CONDUCTED AFTER PCK FOR NOS INSTRUCTION

MÜLAKAT SORULARI

5. Kimya öğretiminin amacı nedir?
6. Kimya öğretimi sonucunda öğrencilerinin sahip olmasını bekledigin bilgi/beceri/kazanım vb. nelerdir?
7. Öğrencilerin açısından bahsettigin bilgi/beceri/kazanımlara sahip olmak neden önemlidir?
8. Kimya öğretiminin amacı ve öğrencilerinin sahip olmasını beklediğin bilgi/beceri/kazanımlar açısından sahip oldugun görüşlerde NOS öncesi NOS sonrası ve PCK for NOS sonrası bir değişim oldu mu? Görüşlerini karşılaştırabilir misin? Olduysa nasıl?
9. Öğrencilerinin bilimin doğasını öğrenmeleri gerektiğini düşünüyor musun? Bu görüşünde NOS öncesi, NOS sonrası ve PCK for NOS sonrası bir değişim oldumu? Görüşlerini karşılaştırabilir misin? Olduysa nasıl?
10. Bahsettigin bilgi/beceri/kazanımlara ulaşmanı sağlamak için nasıl bir öğretim tasarlarsın?
11. Öğrencilerinin bilimin doğasını öğrenmesi gerektiğini düşünüyorsan böyle bir derste kullanabileceğin öğretim stratejileri neler olabilir? Bu stratejiler hakkında düşüncelerini oluşturmanda NOS öğretiminin ve PCK for NOS öğretiminin katkısı nedir? Hangi metodun diğerlerine göre daha etkili olduğunu düşünüyorsun? Açıkla.
12. Bahsettigin bilgi/beceri/kazanımlara ulaşman için tasarladığın öğretimde öğrencilerin var olan bilgileri öğretimini nasıl ve ne derece etkileyebilir?
13. Öğrencilerinin bilimin doğası hakkında kafalarında olabilecek düşünceler nelerdir? Var olabilecek düşünceler hakkındaki görüşler hakkındaki

farkındalığını NOS öncesi, NOS sonrası ve PCK for NOS sonrası olarak karşılaştırabilir msin?

14. Tasarladığın öğretimi uygularken ne tür zorluklarla karşılaşabilirsin?
15. Bahsettigin bilgi/beceri/kazanımlara ulaşılıp ulaşılmadığını anlamak için nasıl bir değerlendirma yaparsın?
16. Öğrencilerinin ulaşmayı hedeflediğin bilimin doğası boyutları hakkında yeterli bir düzeyde anlayışa sahip ıolup olmadığını nasıl anlarsın? Ne tür ölçme ve değerlendirme metodları kullanırsın? Kullanacağın ölçme ve değerlendirme metodları hakkındaki görüşlerini NOS öncesi, NOS sonrası ve PCK for NOS sonrası olarak karşılaştırabilirmisin?
17. Take home ödevini yaparken kimya konusunu belirlemende önemli olan faktörler neler oldu? Sence bilimin doğasının tüm kimya konularında vurgulanabileceğini düşünüyor musun?
18. Kimya öğretimine bakış açını NOS öncesi NOS sonrası ve PCK for NOS sonrası olarak karşılaştırabilir miisn?
19. Dersin bir değerlendirmesini yapacak olursan neler söylemek istersin?
20. Bu ders bilimin doğasını öğretmeyi öğretmek açısından hangi açılardan yeterli hangi açılardan yetersiz bir derstir?
21. Sadece NOS öğrenmek NOS öğretmek için yeterli mi?

APPENDIX G

PROFILES of the PARTICIPANTS

Profile of Participant 1	
Participant	Ahmet
Topic	Rate of Reactions
Science Teaching Orientation	• A structure of science (nature of science) • Science, technology and society decisions • Scientific skill development • Everyday Coping/Understand world
SPS objectives	• Experimenting • Communicating • Controlling variables • Predicting • Observing • Designing investigations • Comparing • Inferring • Defining and interpreting variables
NOS objectives	Empirical-based; creativity; socio-culturally embedded
Instructional Strategy	5E (inquiry), explicit-reflective content embedded
Lesson Synopsis	Ahmet designed a 5E lesson plan including two engage; explore, and explain phases. First cycle of 5E focused on the concept of reaction rate and the second cycle aimed to teach effect of temperature on rate of reactions. In the first engage phase, he gave reaction examples from daily life that occur at different rate (e.g., explosion, burning, and rusting), asked for more examples from students and then conducted a discussion on why they occur at different rate and how they can measure the rate of reactions. At the end of discussion, he asked students to design an investigation with the provided materials (Zn or Fe metal, HCl, chronometer, balance, forceps and beaker) where they worked in groups of 3. After students designed and presented their investigation, he conducted a whole class discussion on how rate of reaction is expressed mathematically. In the second engage phase, he asked how they change the rate of reaction occurred between Fe/Zn and acid and provided daily life examples (keeping foods in refrigerator) and again wanted them to design an investigation on determining the affect on temperature on rate of reaction by providing the materials (H_2SO_3, starch, KIO_3, ice, thermometer,

	chronometer, water, and water bath). After students completed their investigation and presented the results, he conducted a discussion on the effect of temperature on rate of reaction and an explicit reflective discussion on empirical-based; creativity; socio-culturally embedded by asking the questions of "Why did each group design a different investigation although they have the same materials?, Did all the groups just used their logic?, What are the factors affecting their design and investigation?, How can you be sure about your ideas on rate of reactions although you are not able to directly see it?, How did they convince the other groups about their results?, and How do you support your claim or confute the other groups' claim?" For extend he asked students to explain some daily life cases (e.g., difference between due dates for different foods, getting spoiled of the foods in warm weather, keeping foods in fridge) based on what they learned about rate of reactions and then administered the crossword for assessing students' understanding of rate of reactions.
Evidence for the components of PCK and connections among them	1. The main purpose of science teaching is to achieve scientific literacy. Thus, students can be more open to scientific developments and understand these developments easily. How science develops, characteristics of scientists, tentative nature of science, and the difference between science and technology should be communicated to students. (Ahmet, Reflection paper #5) (STO) 2. At the end of the lesson, students will be able to understand a. tentative nature of scientific knowledge b. scientists use their creativity and imagination c. scientists are affected by social and cultural values of the society (Lesson plan #2, objectives) (STO) 3. After the second exploration phase, he conducted an explicit reflective discussion on nature of science by asking the questions of "Why did each group design a different investigation although they have the same materials?, Did all the groups just used their logic?, What are the factors affecting their design and investigation?, How can you be sure about your ideas on rate of reactions although you are not able to directly see it?, How did they convince the other groups about their results?, and How do you support your claim or confute the other groups' claim?" (Lesson plan #2) (KoIS) 4. If students have misconceptions and prejudges about nature of science, they may resist learning and may not want to be involved. Identifying these misconceptions is necessary when planning lesson. Based on the identified misconceptions, the lesson is designed and thus students leave the class with more

adequate understanding of science. Students should be involved in the process of science and confronted with their misconceptions. (Reflection paper #5) (KoL, KoIS)

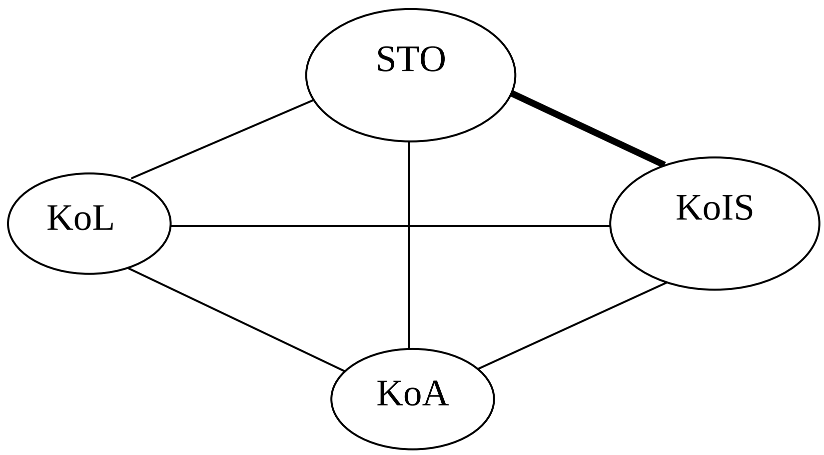
5. Students' misconceptions about nature of science absolutely affect my instruction. One source of these misconceptions is books. These misconceptions are resistant to change. You should create dissatisfaction. It is impossible to change them by using didactic approach. Students should realize that his/her understanding is wrong. (post interview) (KoL, KoIS)

6. Students' understanding of nature of science should be assessed throughout the instruction. You cannot use traditional essay test. You should use different activities...such as preparing a poster or film on nature of science, concept maps, and concept cartoons. Also you can use concept maps and concept cartoons to reveal students' misconceptions at the beginning of the lesson and design your lesson based on what your students' ideas. (post interview) (KoA, KoL, KoIS)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	O		O			✓	✓
KoA	O					✓	✓
KoIS	✓				✓	✓	✓
STO	✓				✓	✓	✓

✓ = present, O=absent; grey= missing data

Post-Intervention PCK for NOS Profile



Profile of Participant 2	
Participant	Ayse
Topic	Chemical Reactions
Science Teaching Orientation	• Science, technology and society decisions • Everyday Coping/Understand world • Self as explainer
SPS objectives	Absent
NOS objectives	Students understands the scientific method by implementing it. The myth of universal and step by step scientific method
Instructional Strategy	Implicit, inquiry
Lesson Synopsis	Ayse's lesson plan is consisting of three parts including introduction, progress, and result. For the introduction part, she asked students to label some changes that they observed in daily life (e.g., cooking, fading of silver, burning of a paper) as physical and chemical (which is previous lesson topic). After students' answer, she explained that the process where chemical change occurs is called as chemical reaction. During progress phase, she explained what chemical reaction is and used question-answer and demonstration method to explain the evidences for chemical reactions. As demonstration she wanted her students to observe what is happening during different chemical reactions that have different evidences (e.g., color change, precipitation, formation of gas, and temperature change). After talking about the evidences for chemical reactions, she asked students to investigate in groups whether all chemical reactions occur in the same way or not by observing what happened during chemical reactions in demonstration. Also, students were expected to form a hypothesis, look for evidences, record what they did during their investigation, and discuss with other groups. After discussion, she labeled different reactions and gave classification. In the result phase, she asked students to construct a concept map where students are free to choose the concepts.
Evidence for the components of PCK and connections among them	1. The purposes of science education are to achieve scientific literacy and to help students to understand and interpret the what is happening in nature. Teachers teach science/chemistry bearing these purposes in mind and students should have the ability to explain scientifically. For instance, a person who does not know biology does not have the knowledge and ability necessary for informed decision making. Individuals should be able to analyze and transfer the knowledge into new situations and should use what they learned in every area of their lives (Ayse, Reflection paper #5) (STO) 2. As demonstration she wanted her students to observe what is happening during different chemical reactions that have different evidences (e.g., color change, precipitation,

formation of gas, and temperature change). After talking about the evidences for chemical reactions, she asked students to investigate in groups whether all chemical reactions occur in the same way or not by observing what happened during chemical reactions in demonstration. Also, students were expected to form a hypothesis, look for evidences, record what they did during their investigation, and discuss with other groups. (Lesson Plan #2) (KoIS)

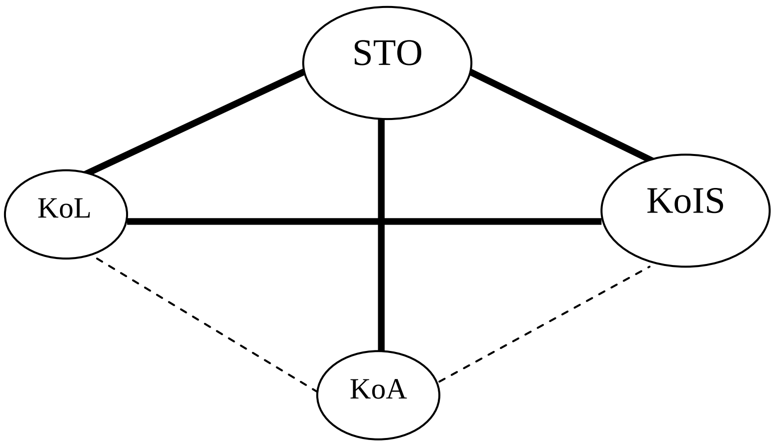
3. During the last for weeks, I learned scientific literacy, misconceptions about nature of science, how I can teach nature of science, and how I can assess nature of science. It was effective in terms of learning to integrate nature of science into chemistry teaching. Also, I learned various assessment techniques that I can use while assessing nature of science. (Reflection paper #5) (STO, KoL, KoIS, KoA)

In the result phase, she asked students to draw a concept map where students are free to choose the concepts. (Lesson Plan #2) (KoA)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	O		O			✓	
KoA	✓				O	✓	
KoIS	✓					✓	
STO	✓					✓	

= present, O=absent; grey= missing data

Post-Intervention PCK for NOS Profile



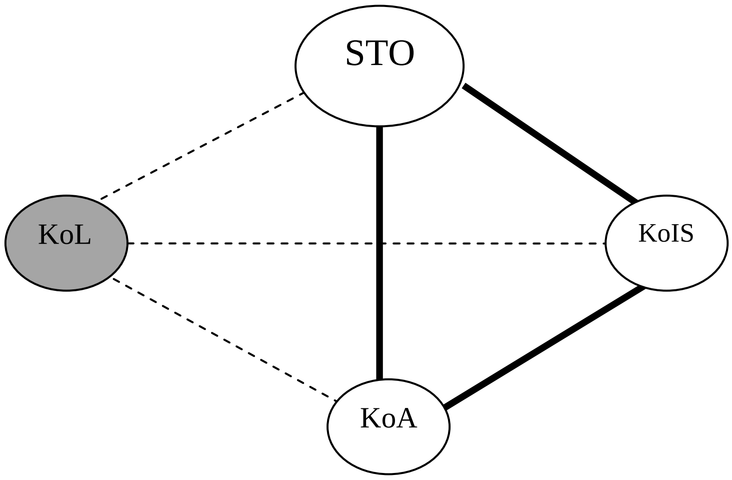
Profile of Participant 3	
Participant	Arda
Topic	Periodic Table
Science Teaching Orientation	• Science, technology and decisions • A structure of science • Self as explainer • Everyday Coping/Understand world
SPS objectives	Absent
NOS objectives	Tentativeness; nature of classification; empirical-based
Instructional Strategy	5E (inquiry), explicit-reflective content embedded
Lesson Synopsis	He used 5E method in his planning. In previous class, he asked students to investigate the scientists who studied on classification on elements and periodic table. For the engage phase, he conducted a whole class discussion on the need for periodic table and the criterion that is used when constructing periodic table. During the exploration phase, he formed 4 groups in class and distributed activity sheets including 15 different elements on each. He asked groups to classify the elements and find the patterns among elements. In the explanation phase, each group presented their periodic table along with their reasoning. After the presentations, he conducted explicit-reflective discussion on nature of science by asking the questions of "What kind of criteria did you use?, Why did you do such kind of classification?, What are you evidences?, May your classification change in near future?, and Why were there various periodic tables proposed in history?" For the extend phase, he discussed the modern periodic table with the class. As an evaluation, he used each group's presentation on periodic table they designed and also, he asked students to collect each others' result and prepare a collective project on periodic table using all the results presented in the class.
Evidence for the components of PCK and connections among them	1. I realized that teaching nature of science within the chemistry concepts is useful in terms of students' science learning. (Arda, Reflection paper #4) (STO) 2. At the end of the lesson, students will be able to understand a. tentativeness of scientific knowledge b. nature of classification c. empirical basis of science (Lesson Plan #2, objectives) (STO) 3. After the presentations, he conducted explicit-reflective discussion on nature of science by asking the questions of "What kind of criteria did you use?, Why did you do such kind of classification?, What are you evidences?, May your classification change in near future?, and Why were there

	various periodic tables proposed in history?" (Lesson Plan #2) (KoIS) 4. As an evaluation, he used each group's presentation on periodic table they designed and also, he asked students to collect each others' result and prepare a collective project on periodic table using all the results presented in the class and reflecting their understanding of nature of science. (Lesson Plan #2) (KoA)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	O						
KoA	✓				O		
KoIS	✓						
STO	✓				✓		

= present, O=absent; grey= missing data

Post-Intervention PCK for NOS Profile



Profile of Participant 4	
Participant	Beste
Topic	Periodic Table
Science Teaching Orientation	• Everyday Coping/Understand world • Scientific skill development-manipulative
SPS objectives	Absent
NOS objectives	Students understands that how periodic table is organized in different points throughout history. (empirical based)
Instructional Strategy	History of science, implicit
Lesson Synopsis	She planned her lesson as introduction, progress, and result. Most of the time she used lecture and question-answer method. As a pre-assignment she asked her students to investigate the historical development of periodic table. In the introduction, she distributed pictures of some elements and asked students what characteristics they will consider if they are asked to group the elements. She stated that she would plan her lesson based on the students' answer. During the progress phase, Beste talked about the criteria used for classifying matter such as physical state, conductivity. Based on the idea of classification of matter, she asked students whether they can classify or group elements and they reached the idea of the need of classifying elements using question-answer method. She concluded that "scientists were investigating characteristics of elements and relationships among them and they were aware the similarities among characteristics of different elements. Scientists realized that there was a pattern in these similarities. Organizing these patterns into a system has been the endeavor of most scientists." Considering what they obtained from their search for the historical development of periodic table, she asked students what they learned and then she lectured about law of triads, octaves, and modern periodic table. In the result phase, Beste made evaluation by asking students to write what they learned from this class to their note cards. After completion of writings, students shared what they learned and Beste lectured about some parts where students have some misunderstanding.
Evidence for the components of PCK and connections among them	1. I realized that I should reveal the meaning students give to concepts about science. I will avoid using sentences that may lead students to the misconceptions about science. (Reflection paper #2, Beste) (KoL, KoIS) 2. Based on the idea of classification of matter, she asked students whether they can classify or group elements and they reached the idea of the need of classifying elements using question-answer method. She concluded that "scientists were investigating characteristics of elements and relationships among them and they were aware the similarities among characteristics of different elements. Scientists realized that

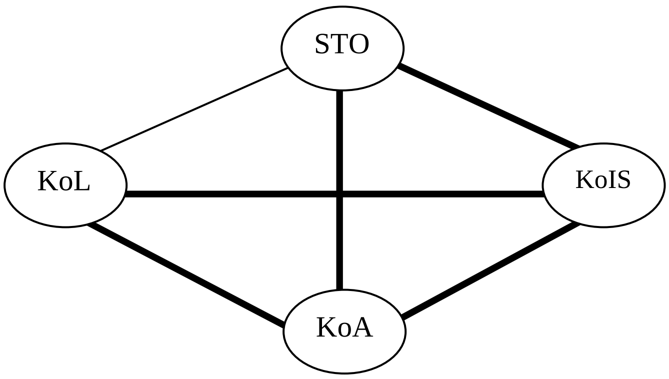
there was a pattern in these similarities. Organizing these patterns into a system has been the endeavor of most scientists." Considering what they obtained from their search for the historical development of periodic table, she asked students what they learned and then she lectured about law of triads, octaves, and modern periodic table. (Lesson Plan #2) (KoIS)

3. I do not think that I wil change my instruction based on what I learned during past four weeks. Even I did not apply directly what we saw, I can use some of student centered teaching and assessment methods to shape my instruction. (Reflection paper #5)
4. The purpose of science education is to help students in familiarizing daily life situations. Science/chemistry topics are directly related to daily life. Students will be able to explain these situations and to see the cause-effect relationship. Students should be successful in cognitive, affective, and psychomotor domain. (Reflection paper #5)
5. Beste made evaluation by asking students to write what they learned from this class to their note cards. After completion of writings, students shared what they learned and Beste lectured about some parts where students have some misunderstanding. (Lesson Plan #2) (KoA, KoIS, KoL)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	O		✓			O	
KoA	✓				O	O	
KoIS	✓					O	
STO	✓	O				O	

✓ = present, O=absent; grey= missing data

Post-Intervention PCK for NOS Profile



Profile of Participant 5	
Participant	Burcak
Topic	Radioactivity
Science Teaching Orientation	• Science, technology and society decisions • Scientific skill development • A structure of science
SPS objectives	Absent
NOS objectives	Observation, inference, and the difference between them; inferential nature of scientific knowledge
Instructional Strategy	Explicit-reflective approach content embedded and content generic
Lesson Synopsis	Burcak told about the Chernobyl disaster and the effect of this disaster on Turkey. Then, she asked students what they think about radioactivity to reveal their pre-conceptions. After revealing students' ideas, she distributed periodic tables to students and asked them to study in groups for finding the radioactive elements in the table and explaining why these elements are radioactive. Groups presented their ideas to the class and Burcak conducted whole class discussion on radioactive elements and the reasons for their radioactive characteristics. After the whole class discussion, she explained what radioactivity is and alpha, beta, and gamma decompositions. Burcak showed a picture of an element nucleus that goes into several decompositions (e.g., positron, neutron, alpha) and asked students to observe and record their observations. She wrote students' observations to the board and then she conducted an explicit reflective discussion on what is observation, what is inference, the difference between them and their role in science by asking the questions of "How did you observe?, What is your observations and inferences?, What is observation and inference?, What are their roles in science?". Moreover, she showed a picture including images of five senses in order to eliminate the misconception that observations are made through the sense of seeing. Then she showed two gestalt pictures, asked them to observe and discussed with the class about the role of inference in science and to overcome students' misconceptions (Scientific knowledge is based on the only careful observations. There is no room for inference.) At the end, Burcak asked students to classify their observations and inferences that they made before. After completion of observation and inference part, she asked students to give daily life usage of radioactivity. She applied diagnostic tree to see whether students achieved the objectives of the lesson and had some misconceptions. Burcak listened students answers for the diagnostic tree and discussed about their answers. At the end, she gave a project work where students work in groups and search for the usage of radioactive elements in scientific research and medical.

Evidence for the components of PCK and connections among them	1. At the end of the lesson, students will be able to understand a. What is observation b. What is inference c. Difference between observation and inference d. Scientific knowledge based on both observation and inference. (Lesson Plan #2, objectives, Burcak) (STO) 2. Possible misconceptions that students may have about the concepts targeted in this lesson; a. Observation is related to the sense of seeing. b. Observation and inference is the same thing. c. Scientific knowledge is based on the only careful observations. There is no room for inference. (Lesson Plan #2, misconceptions) (KoL) 3. I learned possible students' misconceptions about NOS and sources of these misconceptions. I will help my students in eliminating their misconceptions about nature of science since these misconceptions may lead to some prejudges about science and may affect students learning about science. If students overcome their misconceptions, their learning about science will be easier and more conceptual. (Reflection paper #2) (KoL) 4. I learned that learning about nature of science is not an affective objective and cannot be achieved using implicit methods. Instead, it is a cognitive domain objective. Considering this, I will provide students with the opportunities where they reflect on their experiences from the perspective of science. (Reflection paper #3) (KoIS) 5. When I teach nature of science I prefer to use explicit-reflective approach since learning about nature of science is a cognitive domain objective. Students should be provided with the opportunities where they reflect and discuss on their experiences and science. Implicit approach does not work since students have some misconceptions about science that impede their learning or they may have misconception as a result of implicit approach as we have from our own science learning experiences. (Reflection paper #5) (KoIS) 6. Students' pre-conceptions about nature of science especially their misconceptions will absolutely affect my teaching. These misconceptions will make students' learning about nature of science difficult. I will use explicit-reflective approach where I elicit students' ideas and help students to eliminate their misconceptions. (Reflection paper #5) (KoIS, KoL) 7. While assessing nature of science cases, activity sheets, projects, science journal, concept maps, and concept cartoons, and true-false questions can be used for assessing

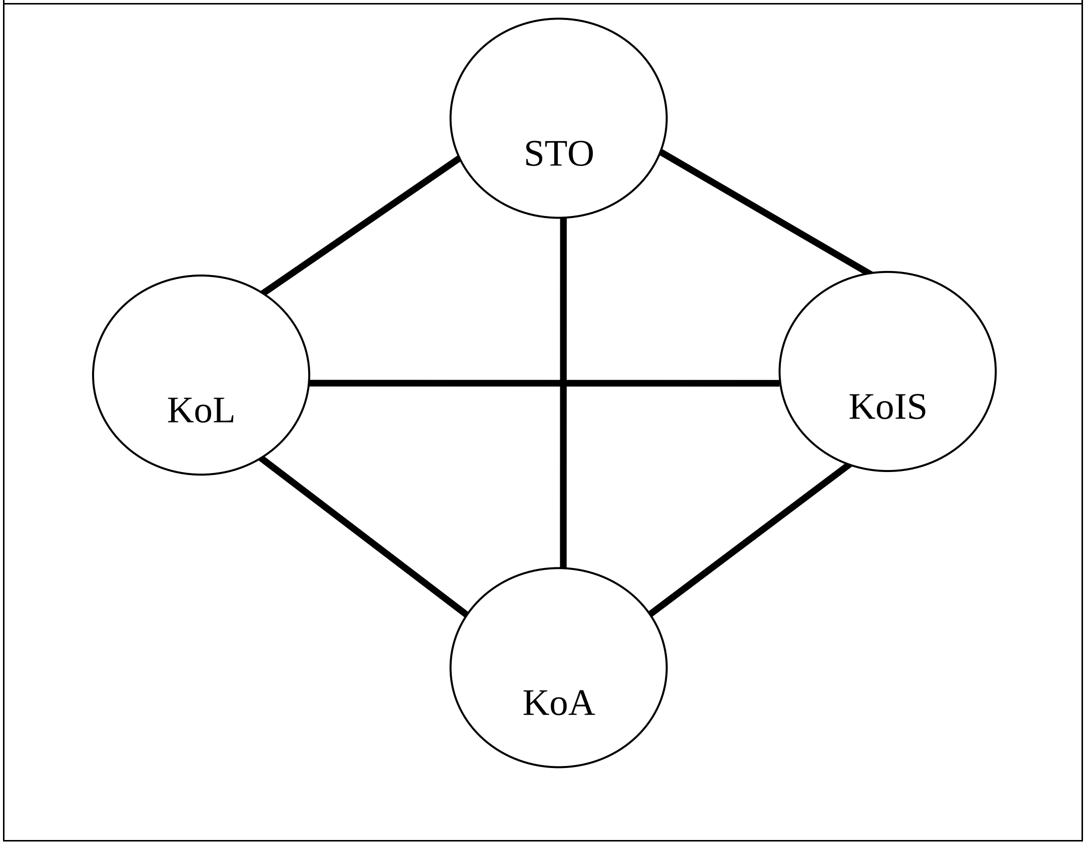
students' understanding about nature of science. (Reflection paper #5) (KoA)

8. I learned why I should assess and how to assess nature of science. By assessing students' understanding about nature of science, we can assess whether students achieve the objectives and the effectiveness of our instruction. Moreover, assessments help us to elicit and eliminate students' misconceptions about nature of science. (Reflection paper #4) (KoA, KoL)
9. Burcak listed the possible misconceptions about nature of science related to the aspects she wants to teach and designed her lesson considering these misconceptions. Burcak showed a picture of an element nucleus that goes into several decompositions (e.g., positron, neutron, alpha) and asked students to observe and record their observations. She wrote students' observations to the board and then she conducted an explicit reflective discussion on what is observation, what is inference, the difference between them and their role in science by asking the questions of "How did you observe?, What is your observations and inferences?, What is observation and inference?, What are their roles in science?". Moreover, she showed a picture including images of five senses in order to eliminate the misconception that observations are made through the sense of seeing. Then she showed two gestalt pictures, asked them to observe and discussed with the class about the role of inference in science and to overcome students' misconceptions (Scientific knowledge is based on the only careful observations. There is no room for inference.) (Lesson Plan #2) (KoIS, KoL)
10. At the end, she asked her students to classify their observations again that they made before. (Lesson Plan #2) (KoA, KoIS)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	✓		✓		✓	✓	
KoA	✓				✓	✓	
KoIS	✓			✓		✓	
STO	✓	✓		✓		✓	

✓ = present, O=absent; grey= missing data

Post-Intervention PCK for NOS Profile

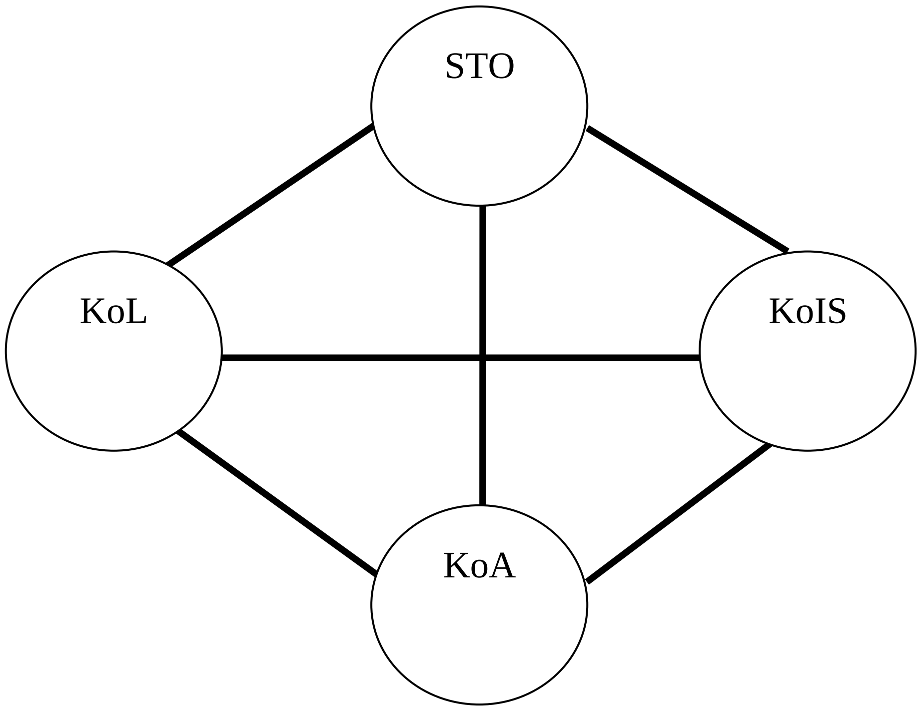


Profile of Participant 6	
Participant	Derya
Topic	Gases
Science Teaching Orientation	• Correct explanation • Scientific skill development • A Structure of science • Science, technology and society decisions
SPS objectives	• Experimenting • Identifying variables • Hypothesizing and testing • Predicting • Controlling variables • Using and interpreting data • Observing • Recording data • Defining variables and interpreting
NOS objectives	Nature of theory, nature of law, and difference between them; tentative and cumulative nature of scientific knowledge; difference between science and technology
Instructional Strategy	5E (inquiry), explicit-reflective content embedded History of science, explicit-reflective content embedded
Lesson Synopsis	Derya used 5E model in her lesson planning. For the engagement, she asked students to draw a concept map using the provided concepts (Celsius, Kelvin, thermometer, thermal expansion, temperature, Boyle Mariotte Law, pressure, gases, ideal gases, real gases, kinetic theory) to reveal their misconceptions and students were free to add new concepts. After completion of concept map, Derya made a demonstration experiment (making and flying a hot air balloon using wooden sticks, candles, plastic bag). After demonstration, she made a whole class discussion about why the balloon flied. Students explained that increase in temperature caused an increase in volume, and the balloon flied. Derya asked students to design an investigation with the given materials (balloon, beaker, ice, water, hot water) for providing evidence for their claims about temperature and expansion. Students worked in groups of 6 and they are asked to form hypothesis, explain their procedure, interpret, and present their results. In the explain phase, Derya explained Charles law based on students' finding about the relationship between temperature and volume. Then, she conducted an explicit reflective discussion on nature of laws and theories by asking the question of "Why do we call Charles Law as law not as Charles theory?", Derya stated some of the possible student answers to that question and she stated it as "Laws have more support/evidence than theories." After that answer she continued to ask questions to dissatisfy students' misconceptions such as "Is the difference related to amount of evidence? Laws have more support than theories?, Could somebody remind us kinetic molecular theory that we learned in previous class? Could somebody explain Charles Law? What is the difference between them? Is there a difference between what they tell us about the phenomena?" With the guidance of Derya, students realized that the nature of theories and laws. Then, she asked students whether laws can change and stated one of the possible answers as "No,

	they cannot." After this answer, she continued to ask questions such as "The difference between theories and laws is not related to amount of evidence they received. If theories can change, why cannot laws? Can we talk about absolute truth in science?" to confront their misconception. After this discussion, Derya made a power point presentation including historical development of Charles Law. She focused on Jacques Alexandre Cesar Charles's education and work (hot air balloon) that lead to development of law. After telling about his work on hot air balloon, she conducted an explicit-reflective discussion on the difference between science and technology by asking the questions of "At the beginning of lesson, I made a flying balloon. While I was making the balloon, did I study as an inventor or a scientist? What makes me scientist and what makes me inventor? What is the difference between scientist and inventor? Can you explain the difference between science and technology based on the difference between scientist and inventor? Moreover, is there a difference between the products of science and products of technology?" After the discussion, she continued her presentation about Charles Law and talked about how Lord Kelvin developed absolute zero based on the knowledge available on Celcius. Then, she asked the question "What can you say based on how Kelvin developed absolute zero and what kind of knowledge he used?" and conducted an explicit reflective discussion on cumulative nature of science. For the extend phase, she used some concept cartoons to have students apply their understanding of Charles Law to new situations and also, asked students to give examples from daily life. In the evaluation phase, she asked two open ended questions from daily life that require using knowledge about Charles Law.
Evidence for the components of PCK and connections among them	1. At the end of the lesson, students will be able to; a. explain what theory is b. explain what law is c. explain the difference between theory and law d. understand tentativeness of scientific knowledge including laws e. explain the difference between science and technology considering the purpose and product f. understand the cumulative nature of science. (Lesson Plan #2, objectives, Derya) (STO) (KoL) 2. I learned what kind of assessment techniques I can use to assess students' understanding about nature of science. As formative assessment opportunities, I can use activity sheets, projects, science journal, concept maps, and concept cartoons. As summative assessment opportunities, I can use tests, quizzes, and written examination. (Reflection paper #4) (KoA) 3. The purpose of chemistry education is to reach scientific literacy by helping students to understand and gain science

	process skills, nature of science as well as chemistry concepts. (Reflection paper #5) (STO) 4. Students' existing ideas and misconceptions are the things that I should consider when planning my instruction. For eliciting students' misconception I can use short answer questions or ask students to construct a concept map beforehand. I prepare my lesson plan based on students' misconceptions and existing ideas. (Reflection paper #5) (KoA, KoL, KoIS) 5. For the engagement, she asked students to construct a concept map using the provided concepts (Celsius, Kelvin, thermometer, thermal expansion, temperature, Boyle Mariotte Law, pressure, gases, ideal gases, real gases, kinetic theory) to reveal their misconceptions and students were free to add new concepts. (Lesson Plan #2) (KoA, KoL) 6. In the explain phase, Derya explains Charles law based on students' finding about the relationship between temperature and volume. Then, she conducted an explicit reflective discussion on nature of laws and theories by asking the question of "Why do we call Charles Law as law not as Charles theory?", Derya stated some of the possible student answers to that question and she stated it as "Laws have more support/evidence than theories." After that answer she continued to ask questions to dissatisfy students' misconceptions such as "Is the difference related to amount of evidence? Laws have more support than theories?, Could somebody remind us kinetic molecular theory that we learned in previous class? Could somebody explain Charles Law? What is the difference between them? Is there a difference between what they tell us about the phenomena?" (Lesson Plan #2) (KoA, KoIS, KoL) 7. She focused on Jacques Alexandre Cesar Charles's education and work (hot air balloon) that lead to development of law. After telling about his work on hot air balloon, she conducted an explicit-reflective discussion on the difference between science and technology by asking the questions of "At the beginning of lesson, I made a flying balloon. While I was making the balloon, did I study as an inventor or a scientist? What makes me scientist and what makes me inventor? What is the difference between scientist and inventor? Can you explain the difference between science and technology based on the difference between scientist and inventor? Moreover, is there a difference between the products of science and products of technology?" (Lesson Plan #2) (KoIS, KoL) 8. In my second lesson plan, at the beginning I used concept mapping to reveal their misconceptions. Also, the question that I asked was directed towards to elicit their misconceptions about nature of science. In my first lesson plan, I taught nature of science implicitly and I did not think that I should assess it.

	In my second lesson plan, I preferred to use informal ways-the questions that I asked throughout my explicit reflective discussion. (post interview) (KoA, KoL)						
	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	✓		✓			✓	✓
KoA	✓				✓	✓	✓
KoIS	✓			✓		✓	✓
STO	✓	✓	✓			✓	✓
✓ = present, O=absent; grey= missing data							
Post-Intervention PCK for NOS Profile							



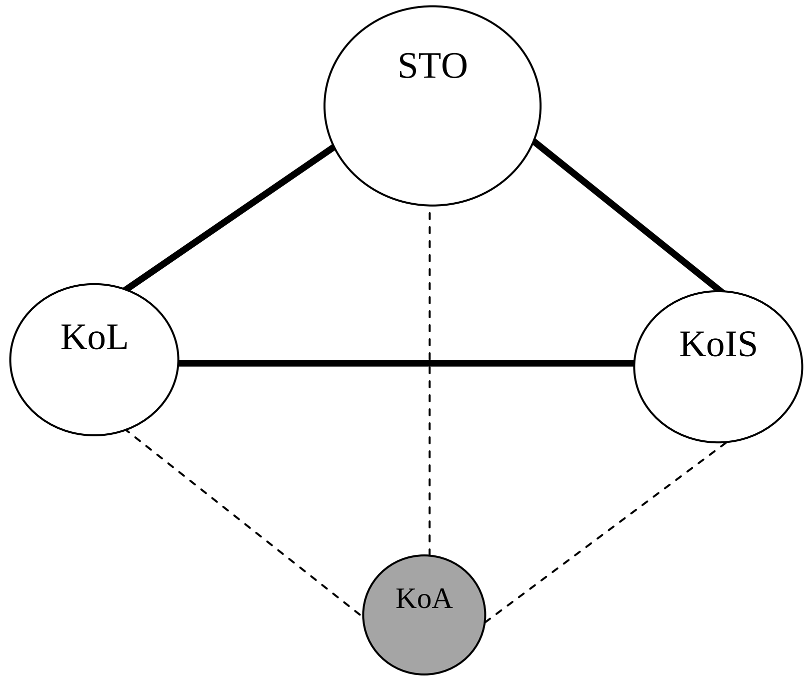
Profile of Participant 7	
Participant	Ebru
Topic	Rate of Chemical Reactions
Science Teaching Orientation	• A Structure of science • Science, technology and society decisions • Everyday Coping/Understand world • Self as explainer
SPS objectives	• Experimenting • Modeling • Interpreting data • Communicating • Observing • Relating • Recording data
NOS objectives	The role of logic and creativity in science, the myth of there is a universal and step by step scientific method exists
Instructional Strategy	5E (Inquiry) Explicit-reflective approach, content embedded
Lesson Synopsis	Ebru used 5E model in her lesson planning. She explained that she will ensure that her students will put themselves into scientists' place and understand their activities through engagement in a collaborative scientific process such as hypothesizing, experimenting and observing. She distributed an activity sheet requiring estimating the time for each reaction to occur (burning of a candle, explosion of dynamite, formation of petroleum, burning of coal, and rusting of iron). In the engagement phase, she showed a video for the reactions in the activity sheet and asked them how the rate of reactions can be measured. She explained the criteria for measuring rate of reaction and gave the equation using question-answer method. To teach collision theory, she asked the question of why gas cylinder did not explode without a spark. Then, Ebru asked what is needed for a reaction to occur and received several students' answer such as pressure, temperature. She asked students to form groups and design their investigation to test their hypothesis using the materials provided (HCl solution, ice bath, test tubes, thermometer, Na_2CO_3, beaker, heater). Ebru told her students to see themselves as scientists to investigate rate of reactions and reminded them creativity, thought and knowledge plays an important role throughout scientific investigation. For the exploration phase, before students start to conduct their investigation she showed a video about Big Bang and beginning of the universe. After students watched the video, Ebru asked students to think about the possible hypothesis that scientists formed throughout their scientific research on beginning universe and how they conduct their research to test their hypothesis. Each group presented their ideas about the hypothesis and the way they test their hypothesis. By this way, she found an opportunity to discuss and talk about the myth about the scientific method. Then, students started their investigation where they search for the possible factors influencing the occurrence of reactions. After students completed their investigation, she conducted a whole class discussion on what they found. In the explanation phase,

	Ebru explained collision theory. In the extend phase, she asked students to explain several daily life phenomena (e.g., different due dates for different foods, keeping foods in refrigerator). She thought that she might encounter the misconception of temperature decreases rate of exothermic reactions. To eliminate this misconception, Ebru made a demonstration experiment using $KClO_4$ and M&M's. As an evaluation, she asked students to construct a concept map (concepts are not provided by her) and to keep their activity sheets in their portfolio.
Evidence for the components of PCK and connections among them	1. At the end of the lesson students will be able to understand a. the role of logic and creativity in science b. that there is no universally accepted and step by step scientific method. (Lesson Plan #2, objectives, Ebru) (STO, KoL) 2. The purpose of chemistry education is to achieve scientific literacy. Students should be able to define science and identify the differences between science other ways of knowing. Students who do not have these knowledge and abilities may apply the steps of a scientific method without thinking on it. But it is not the way scientist study.(Reflection paper #5, Ebru) (STO) 3. I learned the importance of eliciting and eliminating the misconceptions about nature of science. I was having misconceptions before this lesson such as there is a universal and step by step scientific method and now I have decided to integrate nature of science into my chemistry teaching. Thus students are involved in the process and study of science and understand the science itself (Reflection paper #5) (STO, KoL, KoIS) 4. For the exploration phase, before students start to conduct their investigation she showed a video about Big Bang and beginning of the universe. After students watched the video, Ebru asked students to think about the possible hypothesis that scientists formed throughout their scientific research on beginning universe and how they conduct their research to test their hypothesis. Each group presented their ideas about the hypothesis and the way they test their hypothesis. By this way, she found an opportunity to discuss and talk about the myth of the scientific method. (Lesson Plan #2) (KoIS)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	✓					✓	
KoA	O					O	
KoIS	✓					✓	
STO	✓	✓				✓	

✓ = present, O=absent; grey= missing data

Post-Intervention PCK for NOS Profile



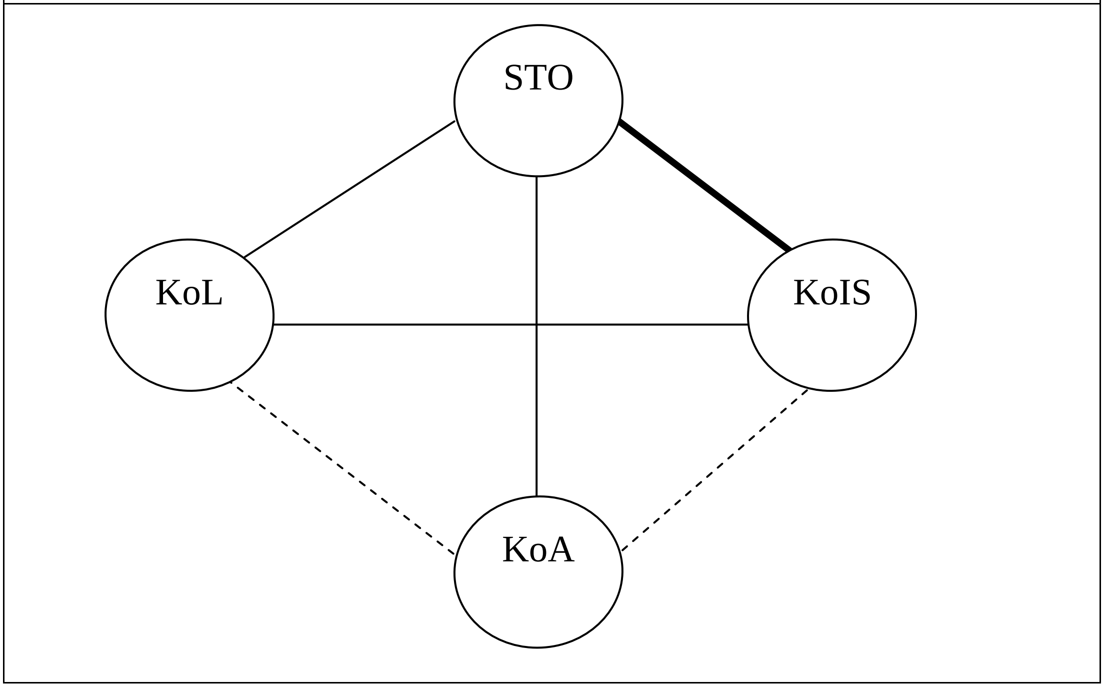
Profile of Participant 8	
Participant	Erdi
Topic	Particulate Nature of Matter
Science Teaching Orientation	• Everyday Coping/Understand world • Science, technology and decisions • A Structure of science
SPS Objectives	Absent
NOS objectives	Observation and inference
Instructional Strategy	5E (inquiry) explicit-reflective approach, content embedded
Lesson Synopsis	Erdi used 5E model to teach particulate nature of matter. For the engagement phase, he told students there are things that they need to think and discuss on in nature. In the exploration phase, Erdi asked students to form groups of four and to try their power for how much they can squeeze the syringe when they close the edge with their finger. Before this try, he asked groups to predict, observe, and draw the model for explaining what they observed. After groups completed their work, each group presented their findings and models with the class. He concluded that the purpose of this activity is to increase students' observation and an inference skill as well as their understanding of matter is consisting of particles. Erdi did another demonstration where students observed how long water stayed in liquid phase while heating it. Also, students and modeled what they observed and the purpose was to deepen their understanding of particulate nature of matter and to increase their observation skills. In the explanation phase, Erdi explained particulate nature of matter. Moreover, he emphasized that looking and seeing and hearing and listening are different from each other. He mentioned that they are involved in the scientific process throughout the lesson. For the extend phase, he asked students to explain what they observe when water poured into a cab including beads in it. Also, Erdi asked to draw a model of a needle to understand whether students can show the particles of it. In the evaluation phase, he administered diagnostic tree including statements related to particulate nature of matter.
Evidence for the components of PCK and connections among them	1. At the end of the lesson students will be able to understand a. what observation is b. what inference is (Lesson Plan #2, objectives, Erdi) (STO) 2. I realized that the science education we took and the words we used in our daily lives (e.g., theory and law) lead to possible misconceptions about nature of science. As a chemistry teacher, I should read history and philosophy of science more and give these examples in my teaching to confront students' misconceptions about science. I will encourage students to express and discuss on

	their ideas. (Reflection paper #2) (KoL, KoIS) 3. Erdi did another demonstration where students observed how long water stayed in liquid phase while heating it. Also, students and modeled what they observed and the purpose was to deepen their understanding of particulate nature of matter and to increase their observation skills. In the explanation phase, Erdi explained particulate nature of matter. Moreover, he emphasized that looking and seeing and hearing and listening are different from each other. He mentioned that they are involved in the scientific process throughout the lesson. (Lesson Plan #2) (KoIS) 4. The idea of teaching nature of science became a purpose of my teaching after the lesson that we talked about swine flu and scientific literacy. (post interview) (STO) 5. I think that nature of science should be integrated within the chemistry content. If we taught nature of science using didactic way students just memorize and the forget it. Students cannot learn nature of science implicitly. Students should learn what science is and how it works using explicit-reflective approach. (post interview) (KoIS) 6. I think that concepts map is aligned with the methods used for teaching nature of science and I prefer to use it to assess nature of science. Also, students can be asked to analyze a case from nature of science perspective. (post interview) (KoA)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	O		✓				✓
KoA	O				✓		✓
KoIS	✓		✓				✓
STO	✓						✓

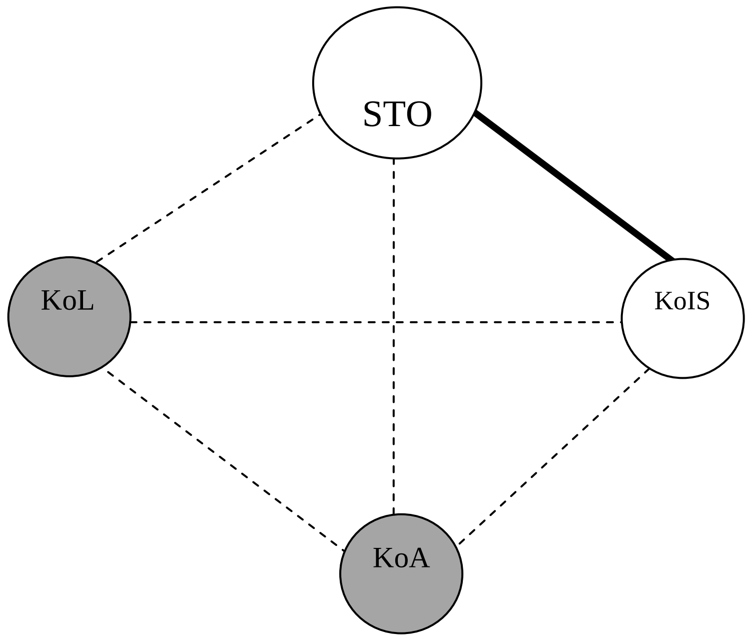
✓ = present, O=absent; grey= missing data

Post-Intervention PCK for NOS Profile



Profile of Participant 9	
Participant	Ferhat
Topic	Atom Models
Science Teaching Orientation	• Scientific Skill Development • Correct Explanation • Self as explainer
SPS Objectives	• Experimenting • Communicating • Relating • Predicting • Observing • Recording data • Comparing • Inferring • Interpreting
NOS objectives	Tentativeness; nature of theory; cumulative nature of scientific knowledge; subjectivity
Instructional Strategy	History of science, explicit-reflective content embedded approach
Lesson Synopsis	Ferhat used history of science and role playing in his teaching of atom models. He prepared the scenarios for Thomson, Rutherford, Bohr, De Broglie, Heisenberg, and Modern Atom Models beforehand and distributed to students and students practiced on their roles before the class with Ferhat. Before students played their roles, Ferhat asked the other students to think on what they can learn about science, scientific knowledge, and scientists and jot them down. After students played their roles, he conducted an explicit-reflective discussion on "What is theory?, Why did scientists need to develop different theories on the same phenomena?, Did scientists use their previous knowledge when developing their theories?, and Did scientists use already existing knowledge in the discipline?" and communicated the aspects of tentativeness and cumulative nature of scientific knowledge; subjectivity and nature of theories.
Evidence for the components of PCK and connections among them	1. Every individual should have adequate understanding about what science is and how it works (reflection paper #5, Ferhat) (STO) 2. At the end of the lesson, students will be able to understand a. tentative nature of scientific knowledge b. cumulative nature of scientific knowledge c. nature of theories d. subjectivity in science (Lesson plan #2, objectives) (STO) 3. After students played their roles, he conducted an explicit-reflective discussion on "What is theory?, Why did scientists need to develop different theories on the same phenomena?, Did scientists use their previous knowledge when developing their theories?, and Did scientists use already existing knowledge in the discipline?" and communicated the aspects of tentativeness and cumulative nature of scientific knowledge; subjectivity and nature of theories. (Lesson Pan #2) (KoIS)

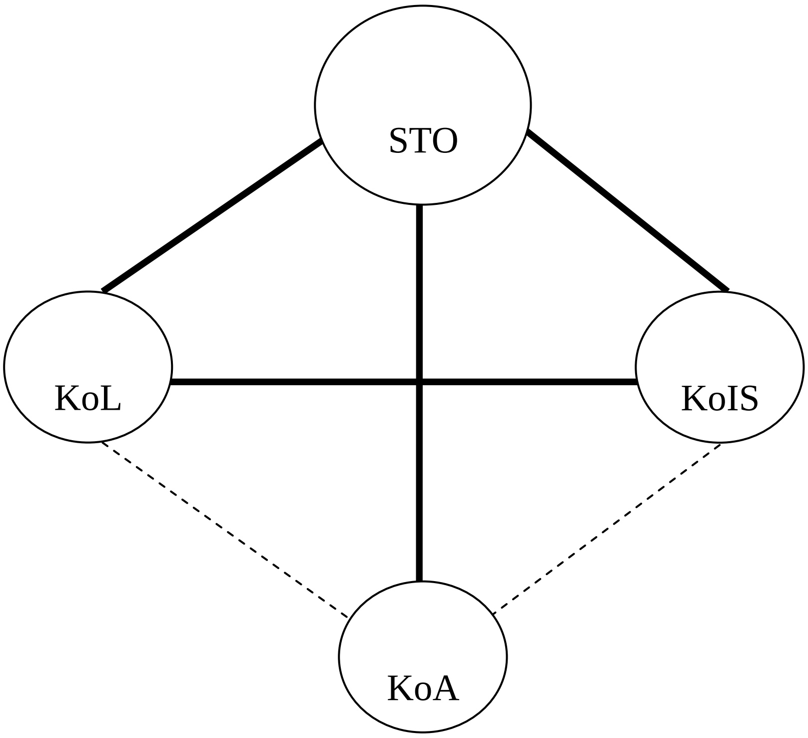
	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	O					O	
KoA	O					O	
KoIS	✓					O	
STO	✓					✓	
✓ = present, O=absent; grey= missing data							
Post-Intervention PCK for NOS Profile							



Profile of Participant 10	
Participant	Figen
Topic	Electrochemistry
Science Teaching Orientation	• Everyday Coping/Understand world • Correct Explanation • A structure of science • Self as explainer
SPS Objectives	Absent
NOS objectives	Observation; inference and difference between them
Instructional Strategy	Guided-inquiry, explicit –reflective content embedded approach
Lesson Synopsis	Figen used guided-inquiry method in her lesson plan. In her explanation, she decided to include a simulation of an electrochemical cell so that she can elicit and eliminate students' misconceptions about electrochemistry (anode is always at right and cathode is at left). Also, she thought that this simulation is useful to teach students observation, inference, and the difference between them. As pre-assignment, she asked students to investigate the daily life usage of batteries and the procedures applied to waste batteries. At the beginning, she conducted a whole class discussion on battery usage in daily life and waste batteries. After engaging students, Figen told class that they will learn the working principles of batteries. She did a simulation as a demonstration experiment. She selected the electrodes and asked students to identify solutions that should be filled into each half cell. After completion of the cell, she asked students' prediction on what will open when they run the cell. Also, Figen asked students to write their observations when the cell is running. She conducted a whole class discussion on what they observe for each electrode and also, conducted an explicit-reflective discussion on observation, inference, and the difference between them by asking the questions of "What is observation?, How did you observe?, What is inference?, and What is the difference between observation and inference?". Figen guided students to infer that there is oxidation where the mass of electrode decreases and there is reduction where the mass of electrode increases. Then, she made a power point presentation on anode, cathode, cell equation, and salt bridge. As an assignment, she asked students to prepare a cell and for the next class explain the cell using their knowledge about electrochemistry and nature of science.
Evidence for the components of PCK and connections among them	1. At the end of the lesson, students will be able to understand a. what observation is b. what inference is c. the difference between observation and inference. (Lesson Plan #2,objectives Figen) (STO) 2. I think that using the simulation of cell is useful to teach

	observation, inference, and the difference between them. Hence, I would integrate nature of science into my chemistry teaching. (Lesson Plan #2) (KoL, KoIS) 3. In her explanation, she decided to include a simulation of an electrochemical cell so that she can elicit and eliminate students' misconceptions about electrochemistry (anode is always at right and cathode is at left). Also, she thought that this simulation is useful to teach students observation, inference, and the difference between them. She did a simulation as a demonstration experiment. She selected the electrodes and asked students to identify solutions that should be filled into each half cell. After completion of the cell, she asked students' prediction on what will open when they run the cell. Also, Figen asked students to write their observations when the cell is running. She conducted a whole class discussion on what they observe for each electrode and also, conducted an explicit-reflective discussion on observation, inference, and the difference between them by asking the questions of "What is observation?, How did you observe?, What is inference?, and What is the difference between observation and inference?". (Lesson Plan #2) (KoIS) 4. Throughout my chemistry teaching, I will integrate several aspects of nature of science such as nature of scientific knowledge, scientific method, observation, and inference. (Reflection paper #5) (STO) 5. I learned how I can assess whether students learned nature of science or not. I learned different assessment methods such as concept maps, concept cartoons, project works, and question-answer method (informal way). (Reflection paper #4) (KoA) 6. As an assignment, she asked students to prepare a cell and for the next class explain the cell using their knowledge about electrochemistry and nature of science. (Lesson Plan #2) (KoA) 7. During past weeks, I realized that I should integrate nature of science into my teaching. Moreover, I should use explicit reflective approach while teaching nature of science. Since students have misconceptions about science, I should elicit their misconceptions before my teaching and eliminate them. (Reflection paper #5) (STO, KoIS, KoL)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	O		✓			✓	
KoA	✓				✓	O	
KoIS	✓					✓	
STO	✓	✓				✓	
✓ = present, O=absent; grey= missing data							
Post-Intervention PCK for NOS Profile							



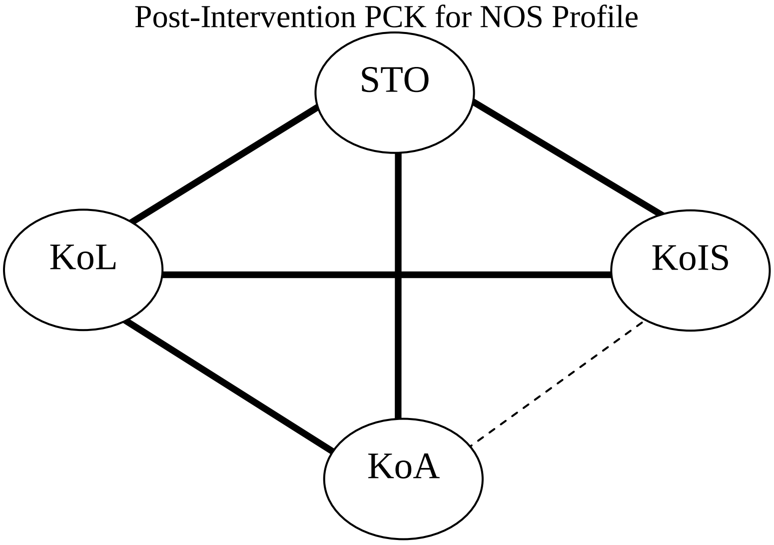
Profile of Participant 11	
Participant	Gozde
Topic	The Mole
Science Teaching Orientation	• Everyday Coping/Understand world • A Structure of science • Self as explainer
SPS Objectives	Absent
NOS objectives	The myth of experiments are the principal routes to scientific knowledge
Instructional Strategy	5E (inquiry) explicit-reflective content embedded approach
Lesson Synopsis	Gozde used 5E model in her lesson planning. In the engagement phase, she had her students to solve a word puzzle where students are expected to find the words which correspond to answers to 10 questions related to the mole concept. For the exploration phase, Gozde asked students to design an investigation in groups to measure the mass of one NaCl crystal by providing the materials. In the explanation phase, each group presented their investigation and findings. After completion of presentations, Gozde conducted a whole class discussion on atomic mass unit and an explicit-reflective class discussion on the myth of experiments are the principal routes to scientific knowledge by asking the questions of “How did you measure the mass of one NaCl crystal?, Did you conduct any experiment or did you just make observations?, Is it possible to produce scientific knowledge without doing an experiment?” In the extend phase, she administered a fill in the gap test relate to the concepts of mole. For the evaluation, she prepared a matching test in order to assess students’ understanding about the mole concept. To assess nature of science, she had her students watch some videos including studies of scientists. Some of the scientists in videos are using experiments and some of them are just using observations. Gozde asked students to differentiate these scientists and their investigations in the video.
Evidence for the components of PCK and connections among them	1. At the end of the students students will be able to understand that experiments are not the principal routes to scientific knowledge (Lesson Plan #2, objectives, Gozde) (STO) 2. In the explanation phase, each group presented their investigation and findings. After completion of presentations, Gozde conducted a whole class discussion on atomic mass unit and an explicit-reflective class discussion on the myth of experiments are the principal routes to scientific knowledge by asking the questions of “How did you measure the mass of one NaCl crystal?, Did you conduct any experiment or did you just make observations?, Is it possible to produce scientific knowledge without doing an experiment?” (Lesson Plan #2) (KoIS)

3. To assess nature of science, she had her students watch some videos including studies of scientists. Some of the scientists in videos are using experiments and some of them are just using observations. Gozde asked students to differentiate these scientists and their investigations in the video. (Lesson Plan #2) (KoA)
4. We learned what kind of assessment strategies we can use to assess students' understanding about nature of science. I realized that I can use different assessment techniques other than traditional essay type questions. (reflection paper #4) (KoA)
5. Throughout the assessment process, different techniques can be used. Havings students to draw concept maps, or interpreting a case using knowledge about nature of science. (Reflection Paper #5) (KoA)
6. Students may have misconceptions about nature of science. Therefore, these misconceptions should be eliminated. Misconceptions should be considered when designing instruction. (Reflection Paper #5) (KoL, KoIS)
7. During past four weeks, I realized that implicit approach id not an effective way for teaching nature of science. Explicit-reflective approach should be used. Also, students' misconceptions about nature of science should be considered during teaching. (Reflection Paper #5) (KoL, KoIS)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	✓					✓	
KoA	✓				✓	✓	
KoIS	✓					✓	
STO	✓	✓	✓	✓		✓	

✓ = present, O=absent; grey= missing data

Post-Intervention PCK for NOS Profile

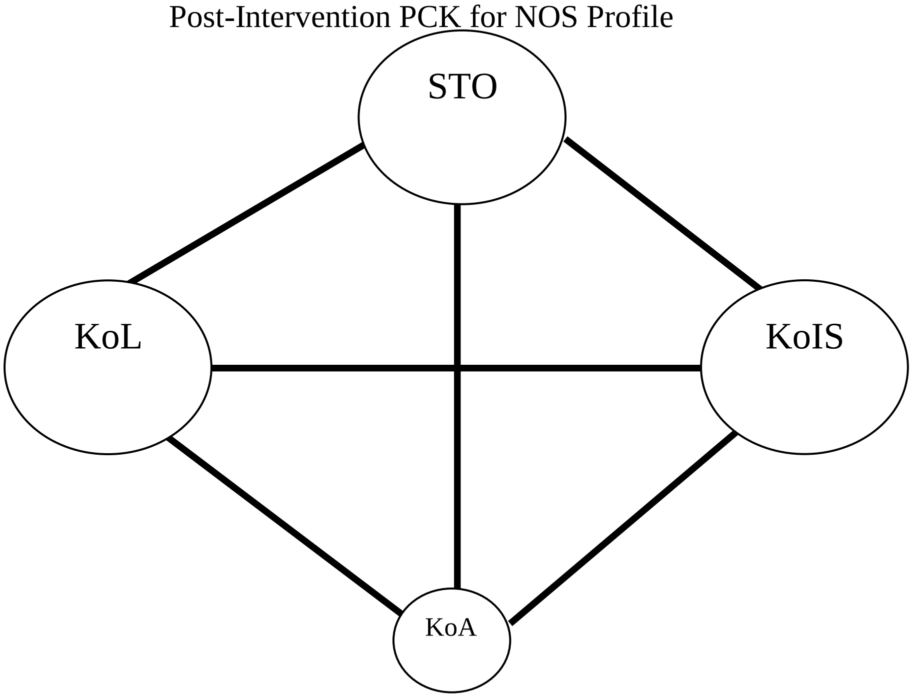


Profile of Participant 12	
Participant	Gaye
Topic	Polarity in Covalent Bonds
Science Teaching Orientation	• Correct explanation • Preparing future scientists • Everyday Coping/Understand world • A Structure of science • Science, technology and society decisions
SPS Objectives	Absent
NOS objectives	Nature of theory, law and hypothesis
Instructional Strategy	5E (inquiry) and history of science, explicit-reflective, content-embedded approach
Lesson Synopsis	Gaye used 5E method in her lesson planning. As a pre-assignment, she asked students to investigate the Gilbert Newton Lewis. For the engagement phase, she had different groups to present what they found. After students shared their findings, Gaye conducted an explicit-reflective discussion on nature of theory and law. She asked the questions of “Why do we call it as Lewis theory although it shed light modern chemistry? and Can there be a Lewis Law?” After the questions, Gaye stated possible answers that students gave to these questions such as; (1) Since the truth of Lewis theory is not proved, it is not called as law, (2) Since it is not directly observable, it stayed as theory. For instance, evolution is a theory and it is not observable too, and (3) The Lewis theory is not accepted by all scientific community and therefore stayed as theory not become a law. After receiving students’ possible answers, she explained that there is difference between the way we used the word theory in our daily life and they way it is used in science (scientific theory) and the continued that If the truth of theories was not proved or theories were not accepted by most of the scientific community, we would not teach and learn in our chemistry or science classes. Also, Gaye gave several examples (e.g., evolution theory, gas laws, kinetic molecular theory) to explain the nature of theories and laws and the difference between them. After completion of the explanation, she asked her students to investigate the concepts of scientific fact, theory, and law for the next class and be prepared to share. For the exploration phase, she asked students to investigate the factors affecting magnetizing degree between iron and magnet. Students investigated in groups and presented their results. Then Gaye explained her students that if they think magnet as nucleus and iron as electrons what they can tell about size of F, N, and O and their electronegativity. In the explain phase, she explained how electronegativity changes across groups and periods. Gaye asked students to give examples of polar and non-polar covalent bonded compound examples for the extend phase. In evaluation phase, she asked students to draw the Lewis dot structure for CS_2, CO_2, H_2O, N_2O_5 and H_2O and determine the type of

	covalent bond.
Evidence for the components of PCK and connections among them	1. At the end of the lesson students will be able to understand a. what theory is b. what law is c. the difference between theory and law (Lesson Plan #2, objectives, Gaye) (STO) 2. After the questions, Gaye stated possible answers that students gave to these questions such as; (1) Since the truth of Lewis theory is not proved, it is not called as law, (2) Since it is not directly observable, it stayed as theory. For instance, evolution is a theory and it is not observable too, and (3) The Lewis theory is not accepted by all scientific community and therefore stayed as theory not become a law. After receiving students' possible answers, she explained that there is difference between the way we used the word theory in our daily life and they way it is used in science (scientific theory) (Lesson Plan #2) (KoL) 3. As a pre-assignment, she asked students to investigate the Gilbert Newton Lewis. For the engagement phase, she had different groups to present what they found. After students shared their findings, Gaye conducted an explicit-reflective discussion on nature of theory and law. She asked the questions of "Why do we call it as Lewis theory although it shed light modern chemistry? and Can there be a Lewis Law?" After the questions, Gaye stated possible answers that students gave to these questions such as; (1) Since the truth of Lewis theory is not proved, it is not called as law, (2) Since it is not directly observable, it stayed as theory. For instance, evolution is a theory and it is not observable too, and (3) The Lewis theory is not accepted by all scientific community and therefore stayed as theory not become a law. After receiving students' possible answers, she explained that there is difference between the way we used the word theory in our daily life and they way it is used in science (scientific theory) and the continued that If the truth of theories was not proved or theories were not accepted by most of the scientific community, we would not teach and learn in our chemistry or science classes. Also, Gaye gave several examples (e.g., evolution theory, gas laws, kinetic molecular theory) to explain the nature of theories and laws and the difference between them. (Lesson Plan #2) (KoL, KoIS) 4. After completion of the explanation, she asked her students to investigate the concepts of scientific fact, theory, and law for the next class and be prepared to share. (Lesson Plan #2) (KoA) 5. In the first part where we learn nature of science, I did not think that nature of science is something that I should teach to my students. In the second part where we learn how to teach nature of science I realized the importance of nature of science for scientific

	literacy and decided to integrate my teaching. Moreover, I was thinking that nature of science can be learned implicitly but through the involvement in explicit reflective approach I saw the effectiveness of it. (post interview) (STO, KoIS)						
	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	✓		✓			✓	✓
KoA	✓					O	O
KoIS	✓					✓	✓
STO	✓	✓				✓	✓
✓ = present, O=absent; grey= missing data							

Post-Intervention PCK for NOS Profile



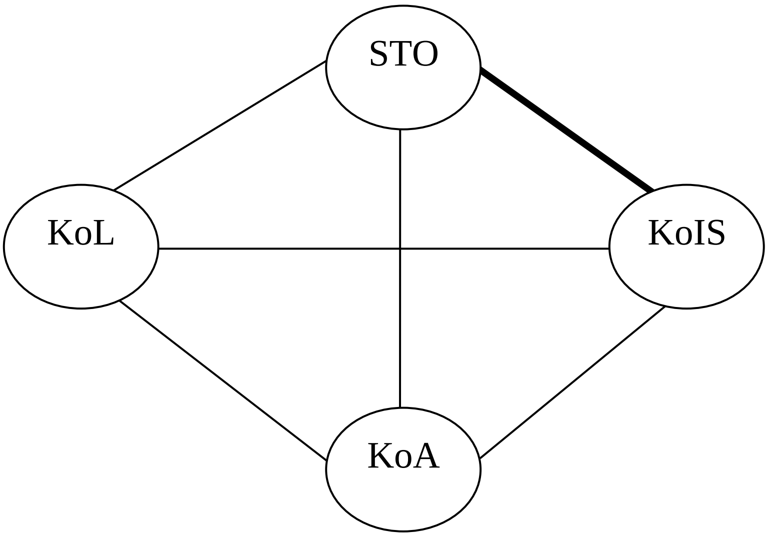
Profile of Participant 13	
Participant	Gokce
Topic	The Mole
Science Teaching Orientation	• Everyday Coping/Understand world • Science, technology and decisions • Scientific Skill Development • A Structure of science • Improving attitudes towards science
SPS Objectives	Absent
NOS objectives	Cumulative nature of scientific knowledge
Instructional Strategy	History of science, explicit-reflective content embedded
Lesson Synopsis	At the beginning of the lesson, Gokce put the pictures of one dozen of pencil, M&M's box, soccer team, and a suit. She asked students to analyze the pictures and find similarities and differences. Gokce wanted to come to idea of all the pictures represents the names given to a group of things or team. After students shared their ideas about the similarities among the pictures and came the idea of giving name to a certain number of objects, she explained the Avogadro Number. Gokce wrote how we call $6.02x10^{23}$ particles (atom, molecule, or ion pairs) in chemistry. Then, she told the historical development Avogadro Number and explained that Avogadro did not find the number actually he proposed that at the same conditions there are same number of gas particles. Gokce mentioned about the others (Josef Loschmindt, Maxwell, Kelvin) who proposed the number of particles that one mole consists of. She concluded that Jean Perrin reached the number that we used today but gave Avagadro's name to that number since he used his ideas. After this historical part, she asked students whether something got their attention about the historical development of Avogadro's Number. Gokce thought that her students can infer that science is cumulative that is use previous knowledge in the field. She emphasized the cumulative nature of scientific knowledge and then solve some algorithmic problems about Avogadro's Number.
Evidence for the components of PCK and connections among them	1. At the end of the lesson, students will be able to understand the cumulative nature of scientific knowledge. (Lesson plan #2, objectives, Gokce) (STO) 2. I realized that our science learning experiences cause misconceptions about science. As I had misconceptions earlier, my future students probably will come to class with similar misconceptions about nature of science. I should communicate adequate understanding about nature of science in my class to eliminate students' misconceptions. (Reflection paper #2) (KoL) 3. I realized that to elicit students' misconceptions and to identify whether students have adequate understanding about NOS, assessing nature of science is very important. We can revise or modify our

	nature of science teaching based on the assessment results. (Reflection paper #4) (KoA, KoL, KoIS) 4. During the past four weeks, I understood how I can integrate nature of science into my teaching. Moreover, I realized that I should be really careful about the misconceptions students have about nature of science. (Reflection paper #5) (KoIS, KoL) 5. I can use concept maps. I can have students to do some projects on nature of scieence.(reflection paper #5) (KoA)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	O		✓			✓	
KoA	O				✓	✓	
KoIS	✓					✓	
STO	✓					✓	

✓ = present, O=absent; grey= missing data

Post-Intervention PCK for NOS Profile



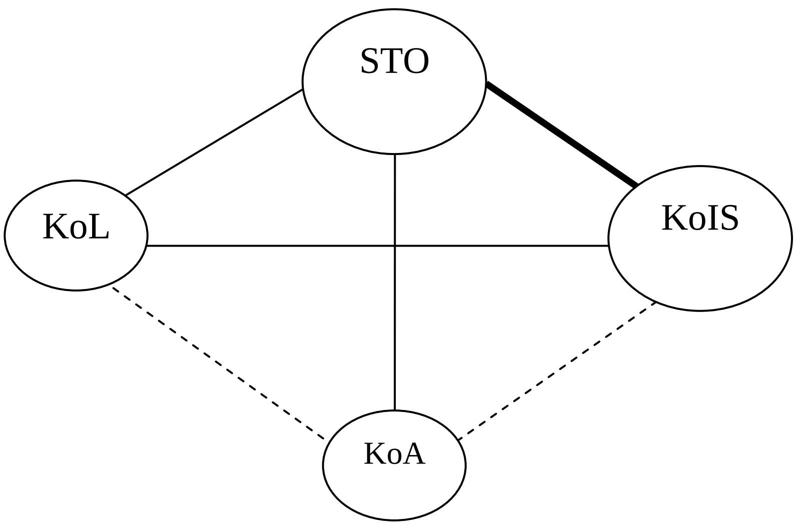
Profile Participant 14	
Participant	Haydar
Topic	Acids and Bases
Science Teaching Orientation	• Science, technology and society decisions • A structure of science • Self as explainer
SPS Objectives	• Experimenting • Hypothesizing • Defining the problem • Inferr ing • Observing • Recording data • Interpreting data • Inferring
NOS objectives	Tentativeness; cumulative nature of scientific knowledge; subjectivity
Instructional Strategy	5E (Inquiry) Explicit-reflective content embedded
Lesson Synopsis	Haydar used 5E model in his lesson planning. For the engagement phase, he made a demonstration using baking soda and lemon. He told that he was following the recipe in his home and there was something interesting happened. He wanted to share this interesting thing with the class and brought baking soda and lemon to the class. Before the demonstration Haydar asked for students' prediction and then put the lemon on baking soda. Students were asked to explain what they observed. He expected that students say that it was an acid and base reaction. For the exploration phase, Haydar asked students to investigate what happens between acids and bases with the provided materials (beaker, $Ba(OH)_2$ and H_2SO_4 solutions, baking soda and lemon) and provide some explanation. After completion of the investigations, groups shared their explanations and investigations. In the explanation phase, he conducted an explicit-reflective discussion on tentativeness, cumulative nature of scientific knowledge and subjectivity asking the questions of "Why there are different explanations about the acids and bases among the groups?, Can your explanation change in future and in which conditions?, and Did you use your previous knowledge about acids and bases when proposing your explanations?" He communicated the tentative, cumulative nature of scientific knowledge and subjectivity and gave examples from the historical development of acids and basis. Then, Haydar explained the neutralization reactions between acids and bases. For the extend phase, he asked students to explain several daily life phenomena (e.g., corrosion of marble by lemon, reaction between vinegar and baking soda, and the reaction between stomach pills and stomach acid). For the evaluation, he distributed students an activity sheet where students should write the products of acid-base reactions.
Evidence for the components of PCK and connections	1. At the end of the lesson students will be able to understand a) tentative nature of scientific knowledge b) cumulative nature of scientific knowledge c) subjectivity in science (Lesson Plan #2, objectives, Haydar) (STO)

among them	2. In the explanation phase, he conducted an explicit-reflective discussion on tentativeness, cumulative nature of scientific knowledge and subjectivity asking the questions of "Why there are different explanations about the acids and bases among the groups?, Can your explanation change in future and in which conditions?, and Did you use your previous knowledge about acids and bases when proposing your explanations?" He communicated the tentative, cumulative nature of scientific knowledge and subjectivity and gave examples from the historical development of acids and basis. (Lesson Plan #2) (KoIS) 3. When I saw the concept cartoons, I realized that there are some students who have various kinds of misconceptions about nature of science that I do not have. I thought that I should elicit students' misconceptions at first. If we ignore the existence of misconceptions, students will not learn targeted nature of science aspects and will continue to keep the misconceptions. (post interview) (KoL, KoIS) 4. I can use concept maps, KWL charts, true-false items, or cases to assess students' understanding about nature of science (post interview) (KoA)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	O		O			✓	✓
KoA	O				O	✓	✓
KoIS	✓					✓	✓
STO	✓					✓	✓

= present, O=absent; grey= missing data

Post-Intervention PCK for NOS Profile



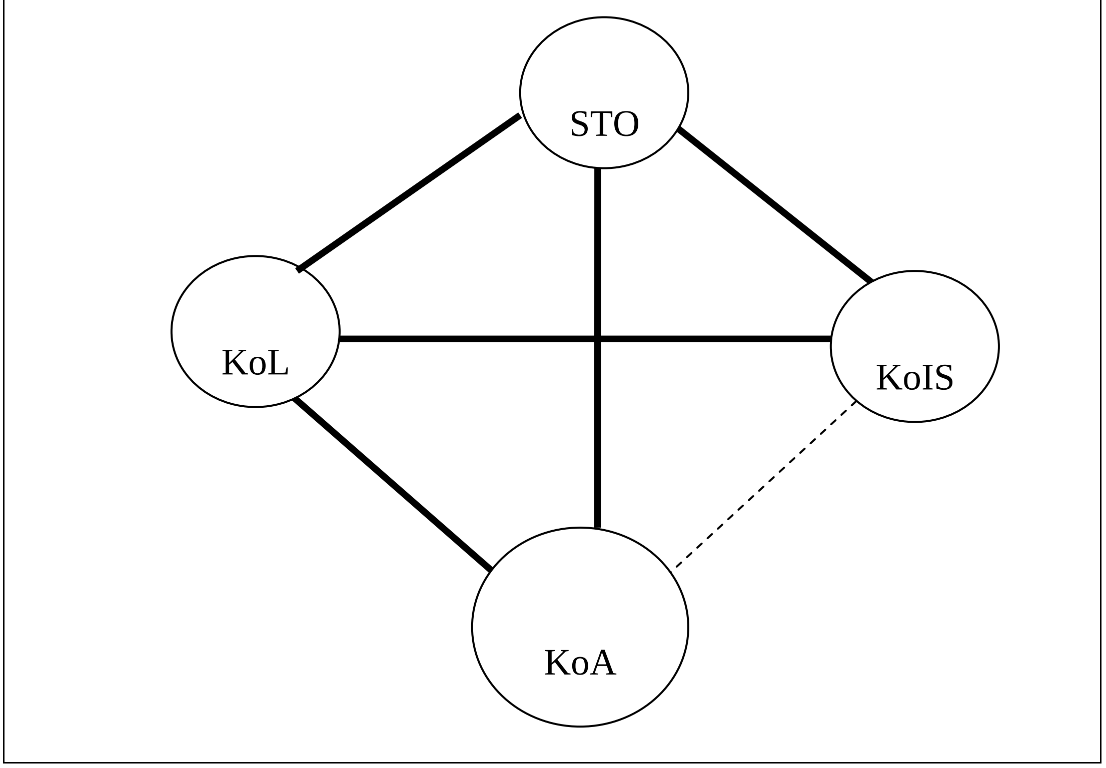
Profile of Participant 15	
Participant	Hale
Topic	Radioactivity
Science Teaching Orientation	• Everyday Coping/Understand world • Science, technology and society decisions • Self as explainer • Scientific skill development-manipulative
SPS Objectives	Absent
NOS objectives	The difference between science and technology in terms of purpose and products
Instructional Strategy	Explicit-reflective approach content embedded
Lesson Synopsis	At the beginning of the lesson, Hale asked students whether they know the daily life applications or the areas where radioactivity is used. After taking students' ideas, she divided the class into three groups and asked groups select one of the three papers where different uses of radioactive isotopes are written on them. The first one included the usage of radioactive elements for activating an automatic valve system that distributes petroleum to different tanks. The second one included usage of radioactive elements (e.g., Co 60, Iodine 131) in the treatment of cancer and thyroid defect. The third one included the usage of radioactive elements in measuring the thickness of a material. Groups were asked to read the papers and to argue on whether these examples are related to science or technology or which part of the example is related to science and which part of the example is related to technology by providing evidence for their claims. Each group presented their claims to the class and then Hale conducted an explicit-reflective class discussion on nature of science by asking the questions of "What is the purpose of science?, What is the purpose of technology?, Can there be technology without science?, Does science and technology affect each other?, Which one, science or technology, exists first?, Does science facilitate our life?, Does technology facilitate our life?, What is the product of science?, What is the product of technology?, and Can you explain which part of the examples represents science an which parts represents technology?" Through these questions Hale communicated the difference between science and technology in terms of purpose and product. As an assessment, she asked students to give examples for both science and technology and she asked others students what they think about these examples.
Evidence for the components of PCK and connections among them	1. At the end of the lesson students will be able to a) differentiate science and technology from each other in terms of purpose and product b) give examples for science and technology (Lesson Plan #2, objectives, Hale) (STO)

	2. Possible misconceptions that students may have about the concepts targeted in this lesson; Science and technology is the same thing. (Lesson Plan #2, misconceptions) (KoL) 3. Each group presented their claims to the class and then Hale conducted an explicit-reflective class discussion on nature of science by asking the questions of "What is the purpose of science?, What is the purpose of technology?, Can there be technology without science?, Does science and technology affect each other?, Which one, science or technology, exists first?, Does science facilitate our life?, Does technology facilitate our life?, What is the product of science?, What is the product of technology?, and Can you explain which part of the examples represents science an which parts represents technology?" Through these questions Hale communicated the difference between science and technology in terms of purpose and product. (Lesson Plan #2) (KoIS) 4. As an assessment, she asked students to give examples for both science and technology and she asked others students what they think about these examples. (Lesson Plan #2) (KoA) 5. I learned what I should pay attention when preparing my lesson plan and assessing nature of science objectives. Some of the possible assessment techniques can be used for nature of science are concept maps, case, concept cartoons, and KWL charts. (Reflection paper #4) (KoA) 6. I am planning to use what I learned about eliminating misconceptions about nature of science in my future chemistry teaching. Because I believe that eliminating students' existing misconceptions about science is very important for helping them in having more adequate understanding of nature of science. (Reflection paper #5) (KoL)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	✓					✓	
KoA	✓				✓	✓	
KoIS	✓					✓	
STO	✓					✓	

✓ = present, O=absent; grey= missing data

Post-Intervention PCK for NOS Profile



Profile of Participant 16	
Participant	Hulya
Topic	Factors Affecting Rate of Dissolving
Science Teaching Orientation	• Everyday Coping/Understand world • Science, technology and decisions • Scientific Skill Development • A Structure of science
SPS Objectives	Absent
NOS objectives	The nature and role of observation and experiment in science, empirical-based ; experiments are the only route to scientific knowledge; there is a general and universally accepted scientific method
Instructional Strategy	5E (Inquiry) Explicit-reflective content embedded
Lesson Synopsis	Hulya used 5E method in her lesson planning. At the beginning of the class, she made a review for the concepts related to solutions that she focused in previous class. In the engagement phase, she asked students to observe rate of dissolving (time passed for sugar to dissolve) of granule, powdered, and cube sugar in three beakers of waters at different temperatures (80°C, 25°C, and 0°C). Moreover, Hulya had her students write their observations and propose an explanation for what they observed. Students worked in groups and after completion of their observations and accompanying explanations, all the groups presented what they had with the class. Then, Hulya conducted an explicit-reflective discussion on the nature of observation and experiment, empirical-basis, and the myth of experiments are the only route to scientific knowledge by asking the questions of “What are their observations?, How did they observe?, Which senses or what did they use?, What are their inferences?, How did they propose their explanations on what they observe?, In what way, observation and inference is different from each other?, Is the observation only way to reach valid and reliable claims in science?, What are the other ways used in science?, Is making experiment possible at all times in science? For the exploration phase, Hulya asked her students to test their explanations by providing the materials (solid $AgNO_3$, small and large granule NaOH, water, chronometer, and beaker) and to write what they did throughout their investigation. After completion of the investigation, each group presented their findings and investigation to the class. Then, Hulya conducted an explicit-reflective discussion on the myth of scientific method by asking the questions of “How did they conduct their investigations?, What were the main processes they were involved? Did they follow a specific order throughout their investigation?, Did every group follow the same steps in their scientific method? If not, why is this so?” In the explanation phase, she explained factors (temperature, surface area) affecting

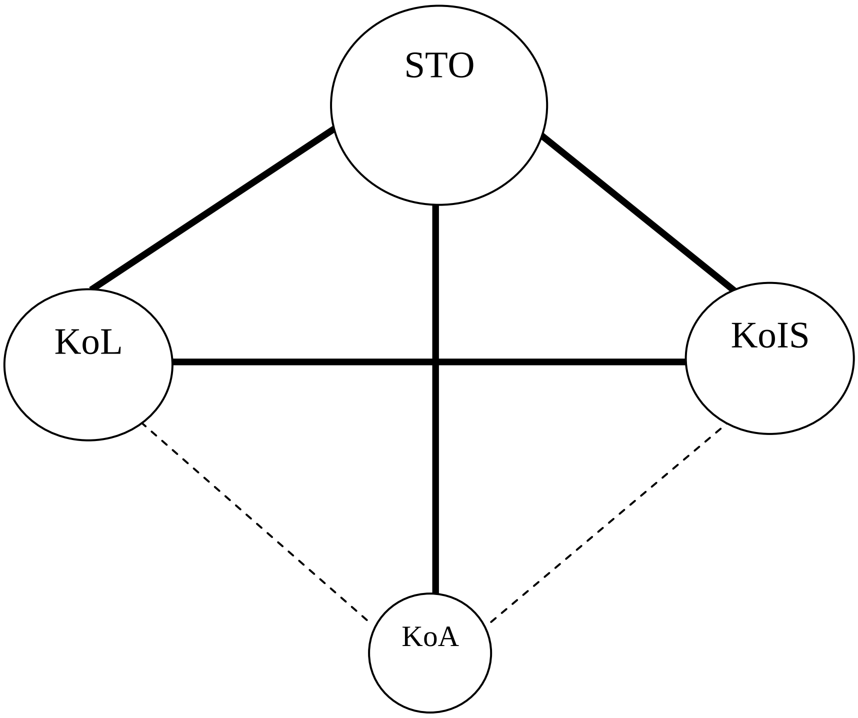
	rate of dissolving by relating students' own explanation and findings. For the extend phase, she asked students to give several daily life examples showing the affect of temperature and surface area on rate of dissolving. Hulya had her students to draw a concept map for assessing their understanding about solutions and dissolving by providing the concepts (e.g., solute, solvent, solution, dissolving, temperature) in the evaluation phase. For assessing nature of science, she preferred to use evidence that she got from explicit-reflective discussions.
Evidence for the components of PCK and connections among them	1. At the end of the lesson, students will be able to understand a. what observation is b. what inference is c. the difference between observation and inference d. empirical-basis of science e. that experiments are not the only route to scientific knowledge f. that there is no universally accepted and step by step scientific method. (Lesson Plan #2, objectives, Hulya) (STO) 2. Then, Hulya conducted an explicit-reflective discussion on the nature of observation and experiment, empirical-basis, and the myth of experiments are the only route to scientific knowledge by asking the questions of "What are their observations?, How did they observe?, Which senses or what did they use?, What are their inferences?, How did they propose their explanations on what they observe?, In what way, observation and inference is different from each other?, Is the observation only way to reach valid and reliable claims in science?, What are the other ways used in science?, Is making experiment possible at all times in science?" (Lesson Plan #2) (STO, KoL) 3. After completion of the investigation, each group presented their findings and investigation to the class. Then, Hulya conducted an explicit-reflective discussion on the myth of scientific method by asking the questions of "How did they conduct their investigations?, What were the main processes they were involved? Did they follow a specific order throughout their investigation?, Did every group follow the same steps in their scientific method? If not, why is this so?" (Lesson Plan #2) (STO, KoL) 4. I want to show my students that chemistry education is not restricted to the information presented in textbooks. I am planning to integrate nature of science into my teaching. (Reflection paper #1) (STO) 5. I learned the importance of understanding and communicating

	nature of science. Moreover, I realized that students may have various misconceptions about nature of science. Being aware of students' misconceptions help me in how to design my instruction. (reflection paper #5) (STO, KoL, KoIS) 6. For assessing nature of science, she preferred to use evidence that she got from explicit-reflective discussions. (Lesson Plan #2) (KoA)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	✓					✓	
KoA	✓					O	
KoIS	✓					✓	
STO	✓	✓				✓	

✓ = present, O=absent; grey= missing data

Post-Intervention PCK for NOS Profile

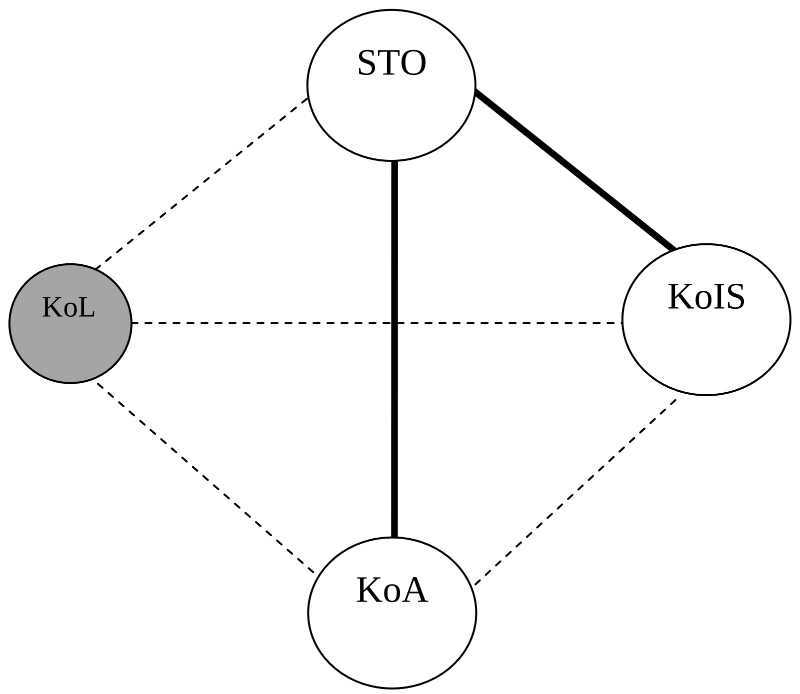


Profile of Participant 17	
Participant	Haki
Topic	Particulate Nature of Matter
Science Teaching Orientation	• Science, technology and decisions • Preparing future scientists • A Structure of science • Everyday coping/Understand world
SPS Objectives	Absent
NOS objectives	Creativity and imagination and the purpose of science
Instructional Strategy	Guided-inquiry, explicit-reflective content embedded
Lesson Synopsis	Haki used a four phase model in his lesson planning including introduction (eliciting students' previous ideas), construction of knowledge, relating with daily life, and evaluation. He stated possible students' answer in his planning and shaped his plan based on these expected answers. In the introduction phase, he stated that most of the things that we encounter in our daily life (e.g, air, animals, plants, table, pencil, and notebook) are matter and asked students "Have you ever thought what matter consists of and nature of matter?" Expected student answer (ESA): Yes or No. Haki (Teacher [T]): Ok, what does the matter consist of?, ESA: Atom, T: How do you know that matter consists of atoms. ESA: Scientists found it. T: Well, How might they have found it? and What did they actually find?, ESA: The desire to understand nature and curiosity are the driving force behind scientists' endeavor and scientists found that there are atoms in matter. T: Did they use their creativity and imagination? ESA: Yes. T: But, we cannot see the atom. How can an invisible thing be found? and How can we accept its reality in 100%? What do you think about the process they propose the idea of atom? ESA: It originated from the desire to understand nature and based on observations scientists collected data about matter. T: Well, Have there been any other scientists thinking about matter? In what way, are the scientists proposing theories or models on nature of matter different from the ones who do not propose theories or models? ESA: They are more creative and imaginative than the others. T: Yes, creativity and imagination plays important role as well as logic in producing scientific knowledge. After these discussions, Haki had students watch a video about the production of scientific knowledge including all scientific process that scientists went through. T: Until now, we have not seen the particles made up the matter but how we can test our idea about nature of matter, something we are not able to see. Now, we will investigate and search for the evidence about particulate nature of matter. (Haki emphasized that he will focus on the myth of scientific method and tentativeness of scientific knowledge later). After that talk, Haki

	had students watched a power point or video about matter. He formed groups according to the class size and distributed two injections to each group Then, Haki asked students to fill one of them with water and the other with air. He told his students to put their fingers to the edge of the injections and observe what happens, propose an explanation about nature of matter, and draw a model for their explanation. (He expected to see that they will squeeze injection with air more) After the completion of their investigation. For the construction of knowledge phase, he conducted a whole class discussion on nature of matter and explicit-reflective discussion on the role of creativity and imagination in science. The questions he asked are "What did you observe?, What is your explanation and model based on what you observed?, We cannot directly see the nature of matter. Did you use only your logic when proposing your explanation and model or did you use your creativity and imagination as well as your logic?" After this discussion part, Haki distributed sugar and water to students and asked them to explain how sugar dissolves in water. He expected from his students to use their knowledge on particulate nature of matter. After talking about students' explanation, he showed a flash animation about particulate nature of matter. For the relating with daily life phase, Haki asked students to give examples from daily life and if they do not give examples he would give several examples (e.g., dissolving, being able to smell the perfume sprayed at another point in the room). In the evaluation, he mentioned that he will do two types of evaluation; one for nature of science and one for particulate nature of matter. He used a diagnostic tree for nature of science (the lesson plan did not include it) and asked students to draw nature of matter and to tell how their ideas change during the lesson.
Evidence for the components of PCK and connections among them	1. At the end of the lesson, students will be able to understand a. the role of creativity and imagination in science b. the purpose of science (Lesson Plan #2, objectives, Haki) (STO) 2. He told his students to put their fingers to the edge of the injections and observe what happens, propose an explanation about nature of matter, and draw a model for their explanation. (He expected to see that they will squeeze injection with air more) After the completion of their investigation. For the construction of knowledge phase, he conducted a whole class discussion on nature of matter and explicit-reflective discussion on the role of creativity and imagination in science. The questions he asked are "What did you observe?, What is your explanation and model based on what you observed?, We cannot directly see the nature of matter. Did you use only your logic when proposing your explanation and model or did you use your creativity and imagination as well as your logic?" (Lesson Plan #2) (KoIS)

	3. In the introduction phase, he stated that most of the things that we encounter in our daily life (e.g, air, animals, plants, table, pencil, and notebook) are matter and asked students "Have you ever thought what matter consists of and nature of matter?" Expected student answer (ESA): Yes or No. Haki (Teacher [T]): Ok, what does the matter consists of?, ESA: Atom, T: How do you know that matter consists of atoms. ESA: Scientists found it. T: Well, How might they have found it? and What did they actually find?, ESA: The desire to understand nature and curiosity are the driving force behind scientists' endeavor and scientists found that there are atoms in matter. T: Did they use their creativity and imagination? ESA: Yes. T: But, we cannot see the atom. How can an invisible thing be found? and How can we accept its reality in 100%? What do you think about the process they propose the idea of atom? ESA: It originated from the desire to understand nature and based on observations scientists collected data about matter. T: Well, Have there been any other scientists thinking about matter? In what way, are the scientists proposing theories or models on nature of matter different from the ones who do not propose theories or models? ESA: They are more creative and imaginative than the others. T: Yes, creativity and imagination plays important role as well as logic in producing scientific knowledge. (Lesson Plan #2) (KoIS) 4. In the evaluation, he mentioned that he will do two types of evaluation; one for nature of science and one for particulate nature of matter. He used a diagnostic tree for nature of science (the lesson plan did not include it) and asked students to draw nature of matter and to tell how their ideas change during the lesson. (Lesson Plan #2) (KoA) 5. I use concept maps, diagnostic tree or crossword to assess students' understanding about nature of science. I believe that nature of science can be communicated with constructivist approach not with the didactic ones. Therefore, assessment should be compatible with our teaching strategy. (Reflection paper #5) (KoA) 6. As a result of my chemistry teaching, the students should conceptualize nature of science. I believe that our teaching should be constructed on the idea of scientific literacy and nature of science is an important component of it. Therefore, I will integate nature of science into my teaching (Reflection paper #5) (STO)

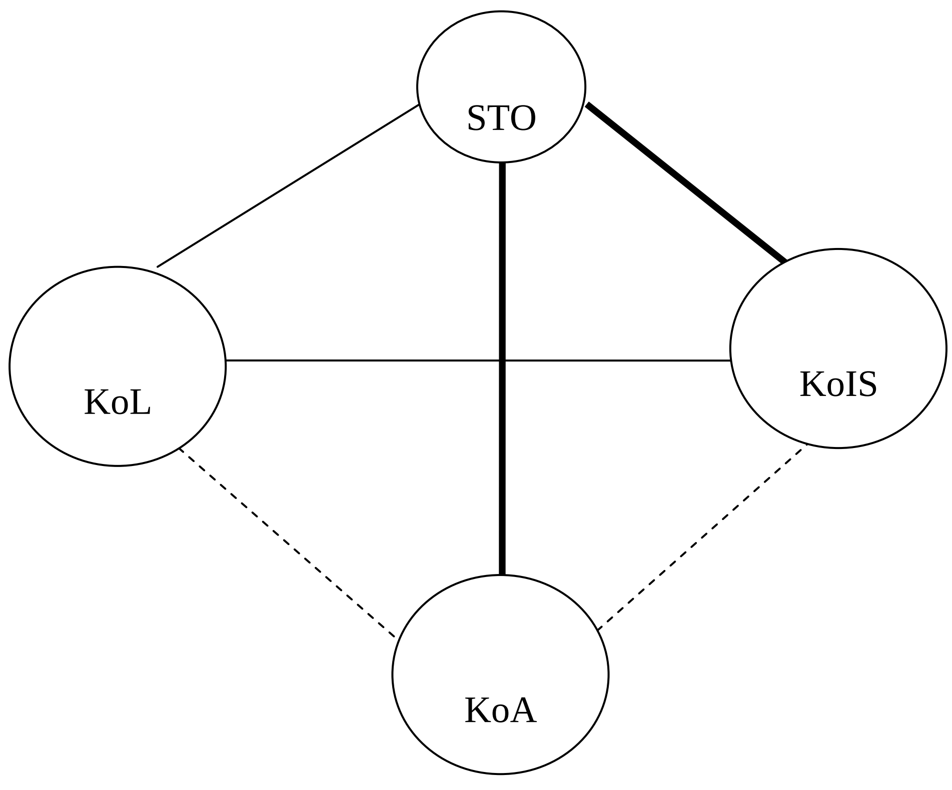
	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	O		O			O	
KoA	✓					✓	
KoIS	✓					✓	
STO	✓					✓	
✓ = present, O=absent; grey= missing data							
Post-Intervention PCK for NOS Profile							



Profile of Participant 18	
Participant	Izzet
Topic	Solutions
Science Teaching Orientation	• Everyday Coping/Understand world • Scientific Skill Development • A Structure of science
SPS Objectives	• Experimenting • Recording data • Interpreting data • Predicting • Observing • Comparing • Inferring
NOS objectives	Cumulative nature of scientific knowledge; empirical-based; nature of classification; subjectivity
Instructional Strategy	5E (Inquiry) Explicit-reflective content embedded approach
Lesson Synopsis	İzzet used 5E model in his lesson planning. He stated expected student answers to the questions he asked and designed his lesson based on these expected answers. For the engagement phase, he told a short story. The story is: We were drinking tea with two of my colleagues. He put 2 cubes of sugar; one of them put 1, and the other put 4. Although we put different amount of sugar in our tea, they all dissolved. Is there a difference among those teas? We put different amount of sugar to the same amount of tea. Can we say that all the teas become the same type of solutions? After that story, students shared their ideas; some of them may say that one of the teas is sweeter than the others and one of them is bitterer than the others. Also some students say that the tastes are different because of concentration difference. After students' responses, Izzet asked students to design an investigation in groups to test their ideas and also, he asked students to write their investigation process, observations, inferences, and whether they support or refute their ideas. During their design and investigation process, he walked around the groups and asked guiding questions in a way that they classify the solutions based on the solute dissolved. After completion of the investigation, all the groups presented their investigation process and their findings. In the explanation phase, İzzet conducted a whole class discussion on saturated, unsaturated, and supersaturated solutions and an explicit reflective discussion on cumulative nature of scientific knowledge, empirical-basis, nature of classification, and subjectivity by asking the questions of "How did you conduct your investigation and come up with your explanation about classification of solutions?, What makes us to believe your investigation and explanation?, How can you be sure about your explanation?, What are the evidences for your explanation?, Did you use your previous knowledge while proposing your explanation?, Why are there different classifications among the groups although you used the same materials?" For the extend phase, he asked students to give daily life examples and gave some examples himself (e.g., crystallizing of honey, coke or soda

	for supersaturated solutions). He asked several essay type and fill in the gaps questions about solution types. Also, he added that students' ideas in class are the informal way for assessing students' understanding about nature of science.
Evidence for the components of PCK and connections among them	1. At the end of the lesson, students will be able to understand a. Cumulative nature of scientific knowledge b. empirical-basis of science c. nature of classification d. subjectivity in science (Lesson Plan #2, objectives, İzzet) (STO) 2. I realized that students may have various misconceptions about nature of science and teachers and instruction are two of the sources of these misconceptipons. I will be carefull about the language I used during my teaching. Since, my language may lead students to some misconceptions such as hierarchical relationship between theory and law. (Reflection paper #2) (KoL, KoIS) 3. Implicit approach is not affective in teaching nature of science. I realized the importance of using explicit-reflective approach for affective nature of science teaching and eliminating misconceptions. Students should be provided with the opportunities where they reflect on their experiences from the perspective on science. Moreover, I realized that assessment should be consistent with instruction and nature of science should be assessed. (Reflection paper #4) (KoIS, KoA) 4. I know that students have misconceptions about nature of science and I will use some instructional strategies to eliminate these misconceptions. I learned how to teach and assess nature of science affectively. I will have students reflect their own experiences from the perspective of science and include several tasks to assess their understanding on nature of science (Reflection paper #5) (KoL, KoIS, KoA) 5. In the explanation phase, İzzet conducted a whole class discussion on saturated, unsaturated, and supersaturated solutions and an explicit reflective discussion on cumulative nature of scientific knowledge, empirical-basis, nature of classification, and subjectivity by asking the questions of "How did you conduct your investigation and come up with your explanation about classification of solutions?, What makes us to believe your investigation and explanation?, How can you be sure about your explanation?, What are the evidences for your explanation?, Did you use your previous knowledge while proposing your explanation?, Why are there different classifications among the groups although you used the same materials?" (Lesson Plan #2) (KoIS)

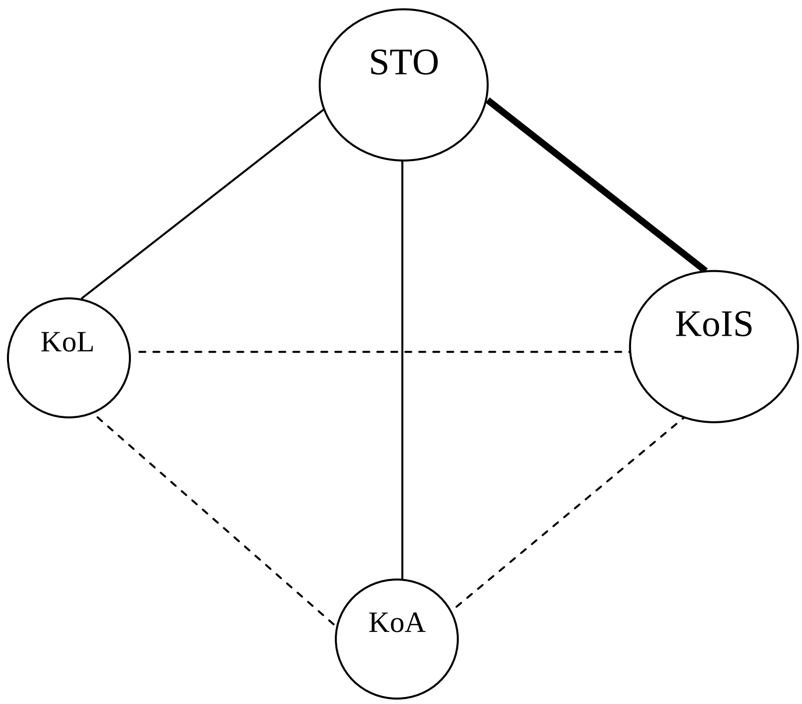
	6. He asked several essay type and fill in the gaps questions about solution types. Also, he added that students' ideas in class are the informal way for assessing students' understanding about nature of science. (Lesson Plan #2) (KoA)						
	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	✓		✓			✓	
KoA	✓				✓	✓	
KoIS	✓			✓		✓	
STO	✓	O				✓	
✓ = present, O=absent; grey= missing data							
Post-Intervention PCK for NOS Profile							



Profile of Participant 19	
Participant	Kader
Topic	Factors Affecting Rate of Reactions
Science Teaching Orientation	• Everyday Coping/Understand world • Scientific skill development-manipulative • Science, technology, and decisions • Thinking on particle level
SPS Objectives	Absent
NOS objectives	Observation; inference; the difference between observation and inference; empirical-basis; creativity and imagination
Instructional Strategy	5E (Inquiry) Explicit-reflective content embedded approach
Lesson Synopsis	Kader used 5E model in her lesson planning. She stated expected student answers to the questions he asked and designed her lesson based on these expected answers. For the engagement phase, Kader showed students the pictures of fresh and moldy bread and fresh and spoiled cheese. She asked students to tell what they see in the pictures. Students told they got spoiled. Kader asked how they can understand whether the foods got spoiled. Students said that changes in appearance, taste, and smell. Kader asked what causes these changes. Students answered there is a chemical change and reaction. She asked what they do to prevent the food to get spoiled. Students said that they keep their foods in fridge. Kader asked why they prefer to keep in cold places. Students told that it takes longer for the foods to get spoiled. She asked what we can say that about how temperature affects rate of reaction. After that discussion, Kader asked students to design an investigation in groups for providing evidence about their ideas on the effect of temperature on rate of reaction and to write their observations, inferences, their procedures, and explanations. She provided materials to the students (0.1 M HCl solution, Na_2CO_3, ice bath, test tubes, thermometer, beaker, gas burner, and chronometer) and explained the reaction occurred between HCl and Na_2CO_3. After completion of the investigation each group presented their investigation and their findings. During the explanation phase, Kader conducted a whole class discussion on the effect of temperature on rate of reaction and collision theory and an explicit-reflective discussion on observation; inference; difference between observation and inference; empirical-basis; and creativity and imagination "What are their observations?, How did they observe?, Which senses or what did they use?, What are their inferences?, How did they propose their explanations on what they observe?, In what way, observation and inference is different from each other?, Is the observation only way to reach valid and reliable claims in science?, What are the other ways used in science?, Is making experiment possible at all times in science?, How can they persuade others for believing their ideas on temperature and rate of reaction?, Why did each group design a

	different way to get evidence for their ideas?, and Did they use their creativity and imagination as well as their logic?". For the extend phase, she asked students to explain some daily life phenomena (e.g., different due dates for different foods, taking longer for nail to get rusted, taking shorter for foods to get spoiled in summer) using what they learned during this lesson. For the evaluation, she administered a crossword that includes concepts related to rate of reaction and collision theory. Also, she asked students draw a concept map using the concepts emphasized for the rate of reaction and collision theory.
Evidence for the components of PCK and connections among them	1. At the end of the lesson, students will be able to understand a. what observation is b. what inference is c. the difference between observation and inference d. empirical-basis of science e. the role of creativity and imagination in science. (Lesson Plan #2, objectives, Kader) (STO) 2. During the explanation phase, Kader conducted a whole class discussion on the effect of temperature on rate of reaction and collision theory and an explicit-reflective discussion on observation; inference; difference between observation and inference; empirical-basis; and creativity and imagination "What are their observations?, How did they observe?, Which senses or what did they use?, What are their inferences?, How did they propose their explanations on what they observe?, In what way, observation and inference is different from each other?, Is the observation only way to reach valid and reliable claims in science?, What are the other ways used in science?, Is making experiment possible at all times in science?, How can they persuade others for believing their ideas on temperature and rate of reaction?, Why did each group design a different way to get evidence for their ideas?, and Did they use their creativity and imagination as well as their logic?". (Lesson Plan #2) (KoIS) 3. Since I have had similar misconceptions before this lesson, I know that it is hard to eliminate students' misconceptions about nature of science. Therefore, I will be careful when teaching ideas about nature of science and try to eliminate misconceptions about nature of science (Reflection paper #2). (KoL) 4. Integrating nature of science into my chemistry teaching will help students to understand science and to better learn the chemistry. Also, I consider assessing students' understanding about the aspects that I taught during my evaluation. (Reflection

	paper #4). (KoA) 5. During the past weeks, I realized the importance of teaching nature of science as well as chemistry knowledge. Also, I learned how I can effectively communicate nature of science aspects to my students (explicit-reflective approach) (Reflection paper #5). (STO, KoIS)						
	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	O		✓			O	
KoA	O				✓	O	
KoIS	✓					✓	
STO	✓					✓	
✓ = present, O=absent; grey= missing data							
Post-Intervention PCK for NOS Profile							



Profile of Participant 20	
Participant	Melek
Topic	Atom
Science Teaching Orientation	• Everyday Coping/Understand world • Science, technology and decisions • Scientific Skill Development • A Structure of science
SPS Objectives	• Experimenting • Exemplify • Data Collection • Observing • Communicating • Data Interpretation • Comparing • Inferring
NOS objectives	Observation; inference; the difference between observation and inference; subjectivity; creativity and imagination; the myth of models are the copies of reality and nature of models
Instructional Strategy	5E (Inquiry) Explicit-reflective content embedded approach
Lesson Synopsis	Melek used 5E model in her lesson planning. As a pre-assignment, she asked students to think on several questions; Do iron, copper, water, iodine, and diamond just consist of atoms?, Can living things consist of atoms?, How many atoms can there be in the onion wall cell that we looked through microscope?, and What can you see if you have the possibility to enlarge and look through atom? For the engagement phase, Melek showed students glass marble and golden ring and asked students "How can the atoms forming golden ring stay together? and Why don't the glass marbles stay stable when we put them on the flat floor?" She aimed to come to the idea of atoms consist of charged particles holding them together. In the exploration phase, she asked students to form groups and to design an investigation to test their ideas, write the whole process and then present their investigation and results including counter and supporting evidences by providing materials (glass marbles, fabric pieces). After completion of the investigations, groups presented their investigations and ideas. Then in the explanation phase, Melek conducted a whole class discussion on nature of atoms (protons, neutrons, and electrons) and an explicit-reflective discussion on observation; inference; the difference between observation and inference; subjectivity; creativity and imagination by asking the questions of "What were your observations?, How did you observe and what did you use throughout your observations?, What were your inferences?, How did you infer?, What is the difference between observation and inference?, Were there different ideas in each group itself?, Can different scientists studying with the same materials have different ideas on the same topic? After the explanation phase on nature of atoms and nature of science, she had her students to design atom models providing the materials (play dough, matchsticks, and readymade atom model sets). Each group designed their own model and

	presented their models with the class. An explicit-reflective nature of science discussion followed the completion of model sharing session. Melek asked students "Why did each group design different model?, Is your model the exact copy of the reality?, Why did we use models in science?, and What is the role of models in science?" She communicated the role of creativity and imagination in science and the role and nature of models in science. Then, Melek communicated the concept of orbit, what differentiates an element from another, isotopes by using question-answer method. In the extend phase, Melek asked students to give daily life examples and re-emphasized the misconceptions a about targeted nature of science aspects. For the evaluation, she asked students to draw a concept map individually related to what they learn about atoms and nature of science. After completion of the individual maps, she drew a whole class concept map on the board using students' ideas and maps and then talked about misconceptions or missing parts if there are.
Evidence for the components of PCK and connections among them	1. At the end of the lesson, students will be able to understand a. what observation is b. what inference is c. the difference between observation and inference d. the role of creativity and imagination in science e. the subjectivity in science f. the role and nature of models in science (Lesson Plan #2, objectives, Melek) (STO, KoL) 2. After completion of the investigations, groups presented their investigations and ideas. Then in the explanation phase, Melek conducted a whole class discussion on nature of atoms (protons, neutrons, and electrons) and an explicit-reflective discussion on Observation; inference; the difference between observation and inference; subjectivity; creativity and imagination by asking the questions of "What were your observations?, How did you observe and what did you use throughout your observations?, What were your inferences?, How did you infer?, What is the difference between observation and inference?, Were there different ideas in each group itself?, Can different scientists studying with the same materials have different ideas on the same topic? After the explanation phase on nature of atoms and nature of science, she had her students to design atom models providing the materials (play dough, matchsticks, and readymade atom model sets). Each group designed their own model and presented their models with the class. An explicit-reflective nature of science discussion followed the completion of model sharing session. Melek asked students "Why did each group design different model?, Is your model the exact copy of the reality?, Why did we use models in science?, and What is the

role of models in science?” She communicated the role of creativity and imagination in science and the role and nature of models in science. (Lesson Plan #2) (KoIS)

3. In the extend phase, Melek asked students to give daily life examples and re-emphasized the misconceptions a about targeted nature of science aspects. (Lesson Plan #2) (KoL, KoIS)

4. For the evaluation, she asked students to construct concept map individually related to what they learn about atoms and nature of science. After completion of the individual maps, she constructed a whole class concept map on the board using students’ ideas and maps and then talked about misconceptions or missing parts if there are. (Lesson Plan #2) (KoA, KoL, KoIS)

5. I realized that students may have misconceptions about nature of science and learned how to eliminate these misconceptions. If we expect our students to have adequate understanding about nature of science, first of all we should eliminate students’ misconceptions about nature of science. In my teaching, I focus on these misconceptions and try to show my students the difference between adequate view and misconception. (Reflection paper #2) (KoL)

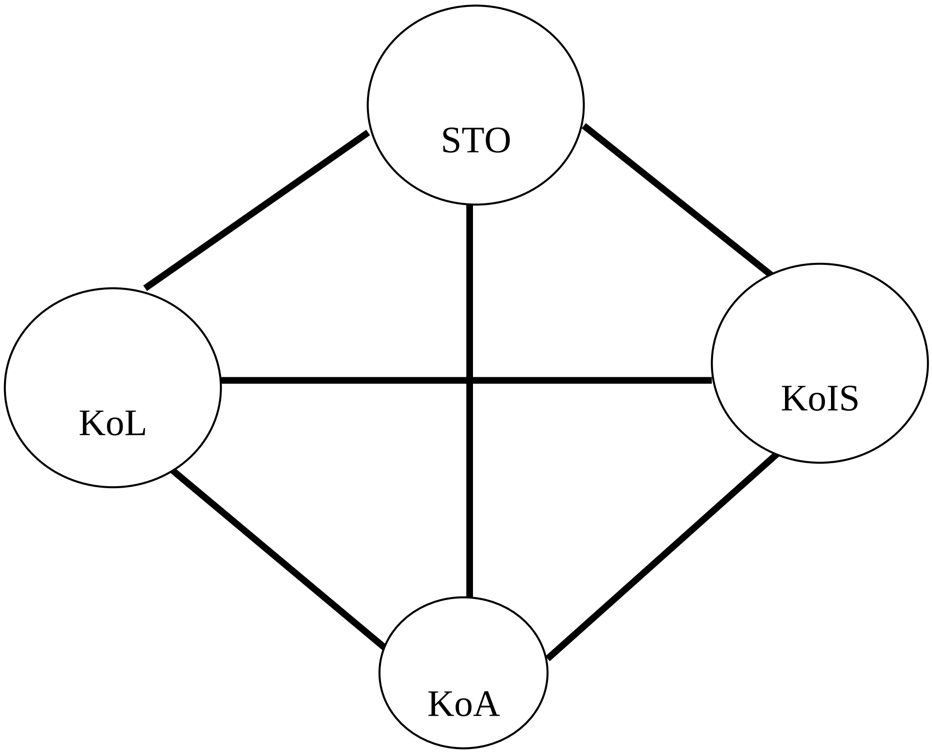
6. Last weeks changed my mind about my future chemistry teaching. I decided to integrate nature of science into my chemistry teaching. Since students have various misconceptions, first of all I elicit students’ misconceptions and eliminate these misconceptions in my instruction. During assessment I also assess students’ understanding about nature of science as well as their chemistry undestanding. (Reflection paper #5) (STO, KoL, KoA)

7. I prefer to use explicit-reflective nature of science teaching embedded in chemistry content since students cannot learn nature of science implicitly. (Reflection paper #5) (KoIS)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	✓		✓			✓	
KoA	✓				O	✓	
KoIS	✓			✓		✓	
STO	✓	✓				✓	

✓ = present, O=absent; grey= missing data

Post-Intervention PCK for NOS Profile



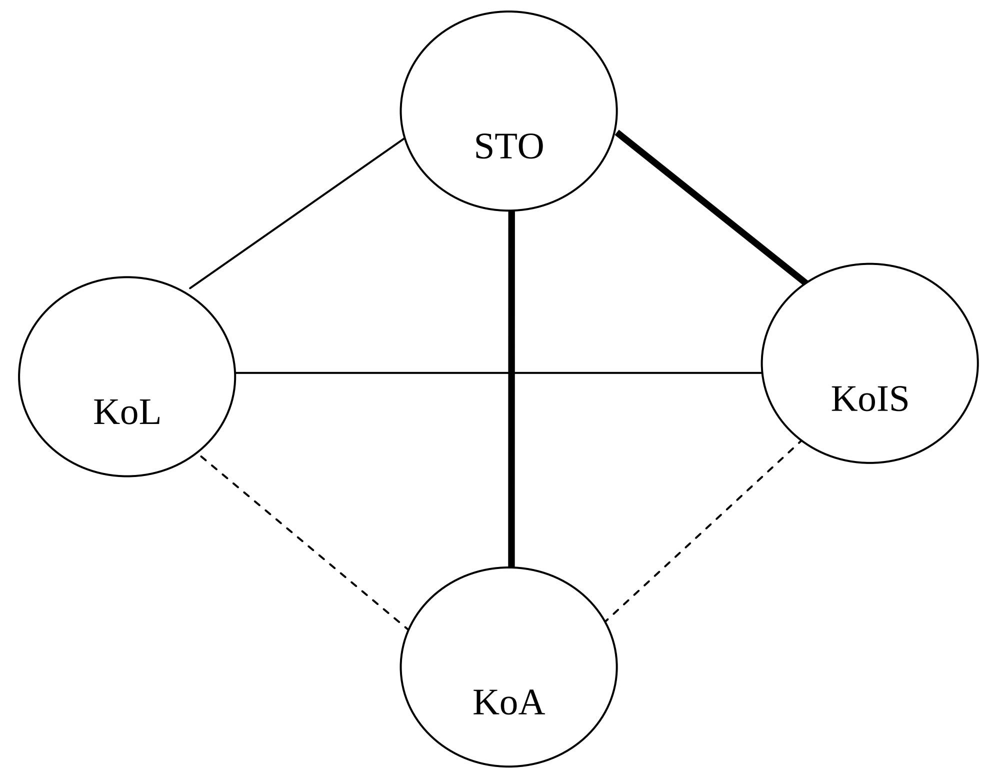
Profile of Participant 21	
Participant	Meral
Topic	Activity
Science Teaching Orientation	• Correct Explanation • Everyday Coping/Understand world • A structure of science • Science, technology and society decisions • Self as explainer
SPS Objectives	• Experimenting • Inferring • Interpretation • Observing • Designing an experiment
NOS objectives	The nature and role of experiments in science; creativity and imagination; and the subjectivity in science
Instructional Strategy	5E (Inquiry) Explicit-reflective content embedded approach
Lesson Synopsis	Meral used 5E model in her lesson planning. For the engagement phase, she asked several questions to students to reveal their previous ideas on metallic activity. These questions are; "Several stuff we used in kitchen is known as silver. But actually, they are silver plated. What do you know about silver plating and plating?, Why do we keep acidic solutions in glass bottles instead of metallic ones?, and How do we decide the oxidizing and reducing species in a red-ox reaction?" In the exploration phase, she asked students to propose an explanation for the phenomenon, design an investigation to test their ideas in groups by providing the materials ($FeSO_4$, $CeSO_4$, $ZnSO_4$, $MgSO_4$, and $SnCl_2$ solutions and copper, zinc, magnesium, and lead metals) write what they did, and present their investigation and findings including supporting and counter evidences. In the explanation phase, Meral conducted a whole class discussion on metallic activity based on the findings students found (e.g., students observed corrosion son some metals and did not observe for some others) and focused on what corrosion indicates (metal loses electrons), what determines the easiness of electron losing, and the concept of metallic activity. Also, she asked students to order the metals based their activity level. Then, Meral conducted an explicit-reflective class discussion on the nature and role of experiments in science; creativity and imagination; and the subjectivity in science by asking the questions of "What are their observations?, How did they observe?, Is the observation only way to reach valid and reliable claims in science?, What are the other ways used in science?, What is experiment?, What is the difference between observation and experiment?, Did each group design the same investigation and interpret the results in the same way?, What are the factors that explain the difference among groups?, Did you use only your logic? or Did you use your creativity and imagination as well as your logic?" For the extend phase, Meral asked student essay type questions (This is the metallic activity order among the

	metals: K, Ca, Mg, Al, Mn, Zn, Cr, Fe, Ni, Sn, Fb, H, Cu, Hg, Ag, Au, and Pt. Which metals leads to formation of H_2 gas when the metal put into HCl solution?) and to give daily life examples on metallic activity. In the evaluation phase, she asked students to construct a concept map with the concepts provided to them. For assessing students' nature of science understanding, she asked students to interpret a case where they should use their knowledge about nature of science.
Evidence for the components of PCK and connections among them	1. At the end of the lesson, students will be able to understand a. the nature and role of experiments in science b. the role of creativity and imagination in science c. the subjectivity in science. (Lesson Plan #2, objectives, Meral) (STO) 2. Before the lesson on scientific literacy, I was thinking that I should just only teach chemistry to my students. Then, I realized the importance of communicating nature of science to my students. Also, students may have various misconceptions about nature of science like I had before. I should eliminate students' misconceptions. Students cannot learn nature of science by themselves using implicit methods. I will use explicit-reflective method embedded in a chemistry topic in my teaching. (reflection paper #3) (STO, KoIS, KoL) 3. Probably, students have various misconceptions about nature of science. I should design my instruction considering these misconceptions since these misconceptions should be eliminated (Reflection paper #5) (KoL) 4. Some of the difficulties that I face when teaching nature of science is related to students' misconceptions about nature of science. I pay attention to my objective related to nature of science; Am I communicating some nature of science aspects or Am I trying to elicit and eliminate students' misconception about related nature of science aspect? This is very important for me. (Post interview) (KoL, KoIS) 5. I learned that I should assess students' understanding of nature of science as well as their understanding of chemistry. Also, I learned new assessment techniques. (Reflection paper #4) (KoA) 6. I can ask students to construct a concept map, to discuss about case and video in order to assess students' understanding about nature of science (Reflection paper #5) (KoA)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	O		✓	✓		✓	✓
KoA	✓				✓	✓	✓
KoIS	✓			✓		✓	✓
STO	✓	✓		✓		✓	✓

✓ = present, O=absent; grey= missing data

Post-Intervention PCK for NOS Profile

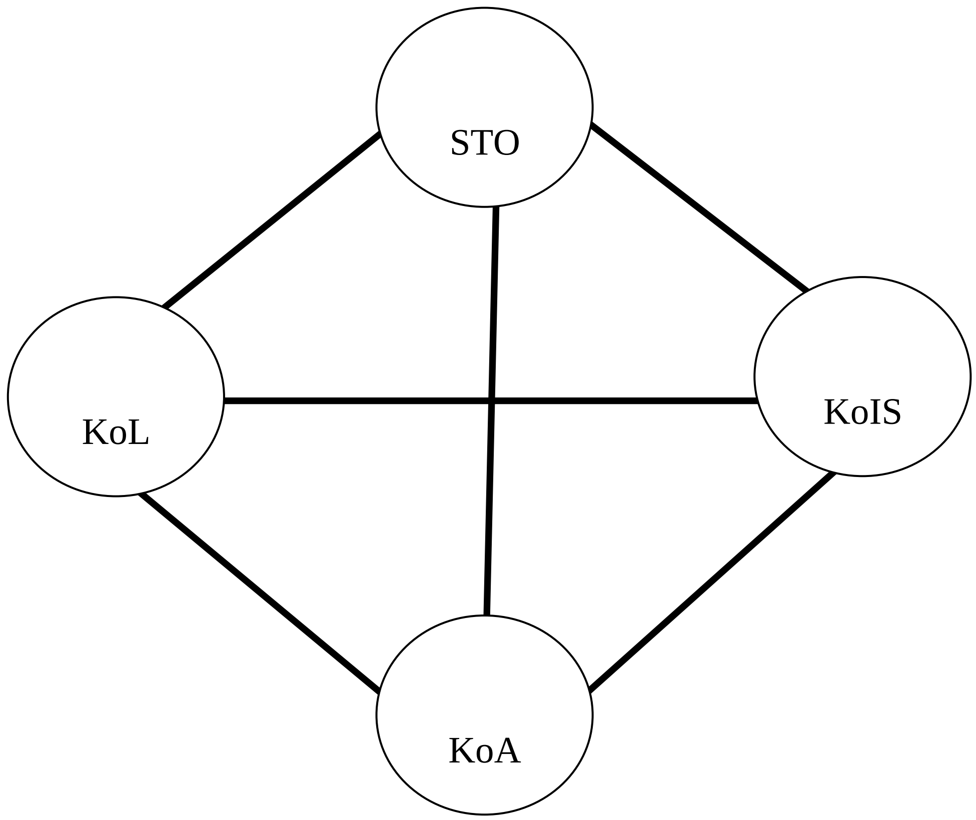


Profile of Participant 22	
Participant	Mehtap
Topic	Covalent Bonds
Science Teaching Orientation	• Everyday Coping/Understand world • A Structure of science • Science, technology and society decisions • Scientific skill development
SPS Objectives	• Experimenting • Inferring • Interpretation • Predicting • Observing • Relating • Comparing
NOS objectives	observation, experiment, scientific knowledge, theory, law, and the characteristics of scientists such as subjectivity, creativity and imagination.
Instructional Strategy	5E (inquiry) explicit-reflective content embedded History of science
Lesson Synopsis	Mehtap used 5E model in her lesson planning. For the engagement phase, she had her students to play the game of pulling rope. In the exploration phase, Mehtap used this pulling rope game as an analog and then conducted a discussion on covalent bonds by asking the questions of "What does this game resemble in physics and chemistry?, Can you think yourself as particles when playing the game?, Why do two atoms compete with each other?, Do you know the nature of salt?, What do you know about Na and Cl elements?, What are the characteristics of metal and nonmetal atoms?, Metals tend to lose electrons and nonmetals tend to accept electrons. What is the driving force that holds metals and nonmetals together?, How do nonmetal atoms exist in nature?, Atomic or molecular?, Is there a chemical bond between the F atoms in F_2?, Is the bond in F_2 ionic? That is, is there an electron transfer?" After the discussion, Mehtap had her students watch a video about the studies of Lewis who proposed the covalent bond in 1916. Following the watching of video, she conducted an explicit reflective discussion on the various aspects of nature of science such as observation, experiment, scientific knowledge, theory, law, and the characteristics of scientists such as subjectivity, creativity and imagination. In the explanation phase, she explained covalent bond and also did some explanations on observation, experiment, scientific knowledge, theory, law, and the characteristics of scientists such as subjectivity, creativity and imagination. At the end of explanation phase, in order to understand whether students still have misconceptions about nature of science Mehtap asked several questions such as "Do theories and laws change?, Are theories and laws discoveries or inventions?, What is the difference between theory and law?, and Why do scientists repeat the measurements?" Also, she asked several questions to check whether students have misconceptions about covalent bonding such as "What kind of image do you have about covalent bonding?, Is covalent bonding something like stick

	or rope as we represent in our models?, and What are the similarities and differences between pulling rope game and covalent bonding?" For the extend phase, Mehtap distributed students papers of which several atomic symbols on it. She selected several couples among the students and asked them to explain the type of atom and type of bond they will form together. Also, she told students about the historical developments of atom models and asked students to interpret the historical case (Rutherford proposed nuclear atom models based on the experiments he did using alpha particles. Thomson and his colleagues studies with alpha particles and found the same results as Rutherford found. Thomson proposed compound scattering theory to explain the scattering of alpha particles with large angels while Rutherford proposed single scattering theory. Why did these two scientists propose two different explanations although they had the same data? In the evaluation phase, she asked students to construct two concept maps (one is for covalent bonding and one is for nature of science) using what they learned about covalent bonding and nature of science.
Evidence for the components of PCK and connections among them	1. At the end of the lesson, students will be able to understand a) the nature of science in general. (Lesson Plan #2, objectives, Mehtap) (STO) 2. After the discussion, Mehtap had her students watch a video about the studies of Lewis who proposed the covalent bond in 1916. Following the watching of video, she conducted an explicit reflective discussion on the various aspects of nature of science such as observation, experiment, scientific knowledge, theory, law, and the characteristics of scientists such as subjectivity, creativity and imagination. In the explanation phase, she explained covalent bond and also did some explanations on observation, experiment, scientific knowledge, theory, law, and the characteristics of scientists such as subjectivity, creativity and imagination. (Lesson Plan #2) (KoIS) 3. At the end of explanation phase, in order to understand whether students still have misconceptions about nature of science Mehtap asked several questions such as "Do theories and laws change?, Are theories and laws discoveries or inventions?, What is the difference between theory and law?, and Why do scientists repeat the measurements?" (Lesson Plan #2) (KoA, KoL) 4. For the extend phase, she told students about the historical developments of atom models and asked students to interpret the historical case "Rutherford proposed nuclear atom models based on the experiments he did using alpha particles. Thomson and his colleagues studies with alpha particles and found the same results as Rutherford found. Thomson proposed compound scattering

	theory to explain the scattering of alpha particles with large angels while Rutherford proposed single scattering theory. Why did these two scientists propose two different explanations although they had the same data?" (Lesson Plan #2) (KoA) 5. In the evaluation phase, she asked students to construct two concept maps (one is for covalent bonding and one is for nature of science) using what they learned about covalent bonding and nature of science. (Lesson Plan #2) (KoA) 6. At the end of explanation phase, in order to understand whether students still have misconceptions about nature of science Mehtap asked several questions such as "Do theories and laws change?, Are theories and laws discoveries or inventions?, What is the difference between theory and law?, and Why do scientists repeat the measurements?" (Lesson Plan #2) (KoL, KoA) 7. Before I was thinking just teaching chemistry concepts to my students. But now, I believed the importance of integrating nature of science into my teaching in order to help my students to better understand chemistry. Implicit approaches and waiting from students to learn nature of science by themselves do not work for teaching nature of science. Explicit reflective approaches where students reflect their own experiences should be used. (Reflection paper #3) (STO, KoIS) 8. Not only students' understandings and misconceptions about chemistry but also their understandings and misconceptions about nature of science should be assessed. I learned various methods for assessing their understanding about nature of science. (Reflection paper #4) (KoA) 9. Misconceptions about nature of science may prevent meaningful learning of nature of science. Therefore, misconceptions should be elicited and eliminated. This is one of the difficulties I may have in my nature of science teaching. (Reflection paper #5) (KoL) 10. Concept maps, cases, and videos can be used to assess students' understanding about nature of science (Reflection paper #5) (KoA).

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	✓		✓			✓	
KoA	✓				✓	✓	
KoIS	✓			✓		✓	
STO	✓			✓		✓	
✓ = present, O=absent; grey= missing data							
Post-Intervention PCK for NOS Profile							



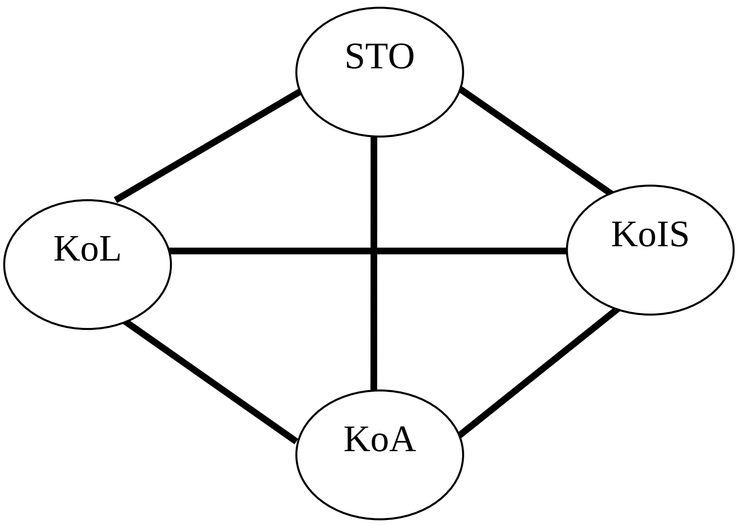
Profile of Participant 23	
Participant	Nilay
Topic	Particulate nature of matter
Science Teaching Orienattion	• Science, technology and decisions • Correct explanation • Everyday Coping/Understand world • A Structure of science • Self as explainer
SPS Objectives	Absent
NOS objectives	Tentative and cumulative nature of scientific knowledge; subjectivity and creativity and imagination in science
Instructional Strategy	5E (inquiry) explicit-reflective content embedded History of science
Lesson Synopsis	Nilay used 5E model in her lesson planning. Throughout her planning, she stated expected student answers (ESA) to her questions and designed her instruction based on these answers. In previous class, students learned that matter consists of mobile particles and there is space among particles. This class, students are going to learn the states of matter. As a pre-assessment she administered 10 questions true-false test to students. Three of the questions were directly related to nature of science; Definitions about the phases of matter is absolute, Scientists produces unchangeable knowledge since they do numerous test, Scientists claim that previous knowledge in the discipline is wrong since they do not like each other. The purpose of administering this test is to elicit students' misconception and design instruction considering students' misconception. In the engagement phase, Nilay collected the 10 questions true-false test and looked at them to see students' misconceptions. She informed students that in previous class they learned about particulate nature of matter and in this class they will look at the subsequent developments and what questions scientists searched for the answers. She made a power point presentation on the historical development using the question-answer method. During the presentation Nilay focused on the ideas and contributions of Thales, Anaximandros, Empedocles, Aristo, Kanada, Leucippu, Democritus, Epicurus, and Lucretius. In the explanation phase, she conducted an explicit-reflective discussion on tentative and cumulative nature of scientific knowledge. After presentation, Nilay (N) asked "Scientists thought and searched for the nature and states of matter throughout the history. If you consider this process for producing scientific knowledge, what are the things that stood out to you? Is there only one and only scientists studied on nature of matter? ESA: Lots of scientists worked on the same topic. N: What else? Did any of them use the already existing knowledge in the discipline? or Did scientists start to work over? ESA: Scientists used the previous knowledge available in the discipline produced by other scientists.

	N: Were the knowledge accepted as absolute or did they change over time? ESA: There was a change in scientific knowledge produced throughout history. Nilay communicated the cumulative and tentative nature of scientific knowledge and then she had students to watch a simulation of three states of matter. After students watched the simulations, they worked in groups and drew how particles situated in each state. Following the completion of group work, students presented their models by creative drama. Nilay conducted a whole class discussion on spaces among the particles and mobility of the particles in three states of matter. Also, she conducted an explicit-reflective whole class discussion on tentativeness, subjectivity and the role of creativity and imagination science by asking the questions of “Which one of the models about states of matter is true? One of the groups or animations? Why are there differences among the models? Did you use your creativity and imagination as well as your logic? In the explanation phase, she explained plasma state of matter and by this way she exemplified the tentativeness of scientific knowledge. Also, Nilay described solid, liquid, and gas states of matter in detail. In extend phase, she asked students to explain what are the microscopic changes occur in particulate level when a solid becomes liquid and then becomes gas. Also, Nilay asked students to give examples from daily life where we can see the compressibility of gases. In the evaluation phase, she asked students to draw a concept map providing the concepts about particulate nature of matter. Also, she asked students to prepare a poster on the areas on which particulate nature of matter shed light on and also, this poster should reflect their understanding of nature of science.
Evidence for the components of PCK and connections among them	1. At the end of the lesson, students will be able to understand a) the tentative nature of scientific knowledge b) the cumulative nature of scientific knowledge c) the subjectivity d) the creativity and imagination in science e) (Lesson Plan #2, objectives, Nilay) (STO) 2. As a pre-assessment she administered 10 questions true-false test to students. Three of the questions were directly related to nature of science; Definitions about the phases of matter is absolute, Scientists produces unchangeable knowledge since they do numerous test, Scientists claim that previous knowledge in the discipline is wrong since they do not like each other. The purpose of administering this test is to elicit students’ misconception and design instruction considering students’ misconception. (Lesson Plan #2) (KoA, KoL, KoIS) 3. Also, she asked students to prepare a poster on the areas on which particulate nature of matter shed light on and also, this

	poster should reflect their understanding of nature of science. (Lesson Plan #2) (KoA) 4. She made a power point presentation on the historical development using the question-answer method. During the presentation Nilay focused on the ideas and contributions of Thales, Anaximandros, Empedocles, Aristo, Kanada, Leucippu, Democritus, Epicurus, and Lucretius. In the explanation phase, she conducted an explicit-reflective discussion on tentative and cumulative nature of scientific knowledge. After presentation, Nilay (N) asked “Scientists thought and searched for the nature and states of matter throughout the history. If you consider this process for producing scientific knowledge, what are the things that stood out to you? Is there only one and only scientists studied on nature of matter? ESA: Lots of scientists worked on the same topic. N: What else? Did any of them use the already existing knowledge in the discipline? or Did scientists start to work over? ESA: Scientists used the previous knowledge available in the discipline produced by other scientists. N: Were the knowledge accepted as absolute or did they change over time? ESA: There was a change in scientific knowledge produced throughout history. (Lesson Plan #2) (KoIS) 5. After students watched the simulations, they worked in groups and drew how particles situated in each state. Following the completion of group work, students presented their models by creative drama. She conducted an explicit-reflective whole class discussion on tentativeness, subjectivity and the role of creativity and imagination science by asking the questions of “Which one of the models about states of matter is true? One of the groups or animations? Why are there differences among the models? Did you use your creativity and imagination as well as your logic? In the explanation phase, she explained plasma state of matter and by this way she exemplified the tentativeness of scientific knowledge. (Lesson Plan #2) (KoIS) 6. During the lesson that we learned how to teach nature of science, I learned that I can both teach chemistry and nature of science at the same time. I will not definitely use implicit approach since I do not think that students can learn nature of science by experiencing the science itself. For instance, in the lesson that we argued about misconceptions about nature of science using concept cartoons if you did not elicit and explicitly discussed about the misconceptions they would have been changed. There should be opportunities for students where they explicitly reflect and discuss on science, scientific knowledge, and scientific method. (post interview) (KoIS)

	7. It is important to elicit students' misconceptions about nature of science for an affective nature of science instruction. If students believe that there is a universal and step by step scientific method or theories and laws do not change, my first goal should be create a conceptual change in students' mind instead of teaching about what theory or law is. After eliminating the misconceptions, the next step would be teaching about theory and law. Students' misconceptions can be identified through the use of concept cartoons, essay type questions. (post interview) (KoL, KoA, KoIS) 8. Instead of directly telling students that their belief about existence of universally accepted step by step scientific method is wrong, students should live and engage in the process of science and then teacher should conduct an explicit reflective discussion on the scientific method. (Reflection paper #5) (KoL, KoIS) 9. Concept maps, concept cartoons, and actvity sheets can be used to assess students' understanding about nature of science. (post interview) (KoA)						
	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	✓		✓			✓	✓
KoA	✓				✓	✓	✓
KoIS	✓			✓		✓	✓
STO	✓	✓		✓		✓	✓
= present, O=absent; grey= missing data							

Post-Intervention PCK for NOS Profile



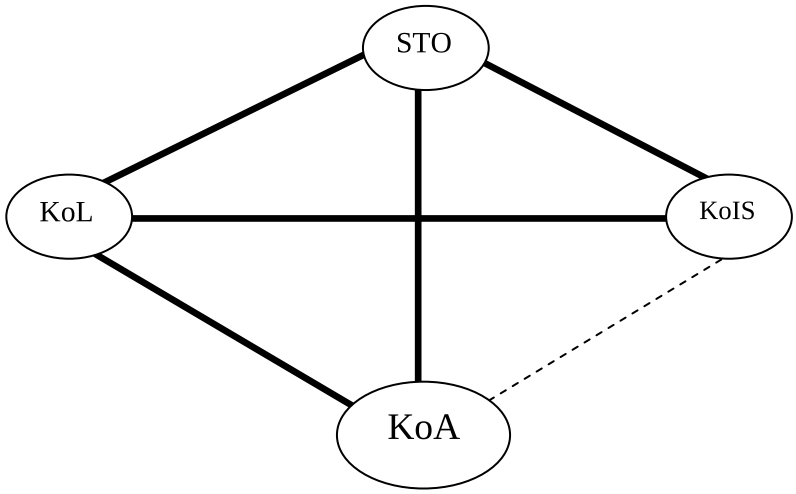
Profile of Participant 24	
Participant	Nurdan
Topic	Chemical Reactions
Science Teaching Orientation	• Everyday Coping/Understand world • Self as explainer • A structure of science • Science, technology and decisions
SPS Objectives	Absent
NOS objectives	The myth of universally accepted and step by step scientific method, what differentiates science from other ways of knowing-theoretical basis of science
Instructional Strategy	5E (inquiry) explicit-reflective content embedded History of science
Lesson Synopsis	Nurdan used 5E model in her lesson planning. In the engagement phase, she asked students a daily life questions to get students' attention: "A corporation decided to hire staff including 20 males and 10 females. There were 30 males and 50 females who applied for the job. The number of staff will be hired is restricted. Does the number of persons applied for the job lead to an increase in the number of staff will be hired?" After students proposed their ideas, she asked "What is element?, What is compound?, How do compounds form?, How is the ratio among the elements that form the compound?, and What is the similarity between staff hiring and compounds?" In the exploration phase, she asked students to design an investigation to test their ideas about the ratio among elements in a compound by providing the materials (sulphur, copper, test tubes, scale, and burner). After students completed their investigation, each group presented their investigation together with their process, what they did, and supporting and counter evidences for their ideas. In the explanation phase, she conducted a discussion on Law of Definite proportions and explained the Law as proposed by Proust in 1799. Also, during the explanation phase, she distributed students a sheet including detailed descriptions of alchemy and chemistry and asked students to find the differences between alchemy and chemistry. Students worked in groups and then presented their ideas to the class. After students' presentation of their ideas Nurdan conducted an explicit-reflective discussion on the myth of universally accepted and step by step scientific method, what differentiates science from other ways of knowing-theoretical basis of science by asking the questions of "What kind of processes were you involved throughout your investigation?, Did each group follow the same process for investigation?, How did you propose ideas about the ratio among the elements in a compound?, Did you use theoretical information that you already know about chemistry?, What makes your investigation process different from the ways used in alchemy?" In the extend phase,

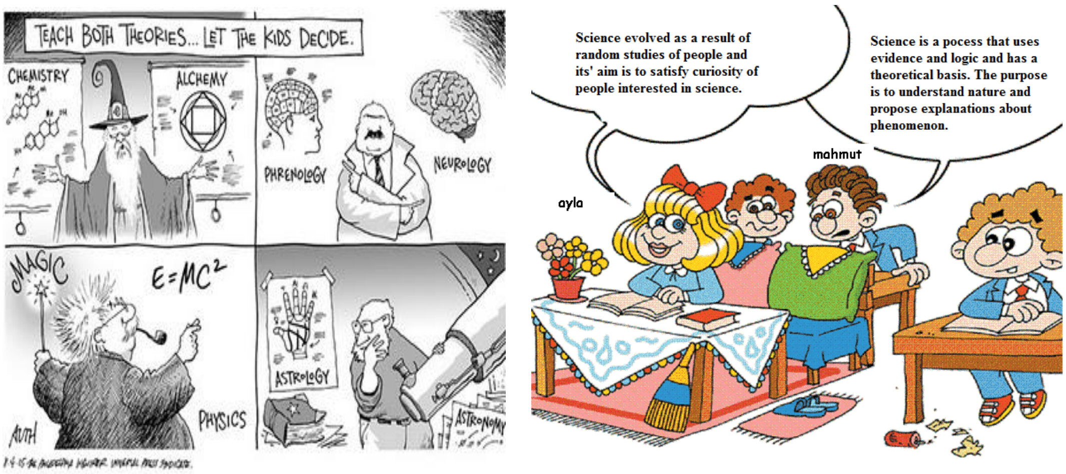
	Nurdan showed two simulations about law of definite proportions and asked students to explain them. For the evaluation phase, she administered a test for assessing students' understanding about law of definite proportions and a concept cartoon and cartoon for assessing students understanding about nature of science.
Evidence for the components of PCK and connections among them	1. At the end of the lesson, students will be able to understand a) that there is no universally accepted and step by step scientific method. b) what differentiates science from other ways of knowing c) theoretical basis of science (Lesson Plan #2, objectives, Nurdan) (STO, KoL) 2. In the exploration phase, she asked students to design an investigation to test their ideas about the ratio among elements in a compound by providing the materials (sulphur, copper, test tubes, scale, and burner). After students completed their investigation, each group presented their investigation together with their process, what they did, and supporting and counter evidences for their ideas. In the explanation phase, she conducted a discussion on Law of Definite proportions and explained the Law as proposed by Proust in 1799. Also, during the explanation phase, she distributed students a sheet including detailed descriptions of alchemy and chemistry and asked students to find the differences between alchemy and chemistry. Students worked in groups and then presented their ideas to the class. After students' presentation of their ideas Nurdan conducted an explicit-reflective discussion on the myth of universally accepted and step by step scientific method, what differentiates science from other ways of knowing-theoretical basis of science by asking the questions of "What kind of processes were you involved throughout your investigation?, Did each group follow the same process for investigation?, How did you propose ideas about the ratio among the elements in a compound?, Did you use theoretical information that you already know about chemistry?, What makes your investigation process different from the ways used in alchemy?" (Lesson Plan #2) (KoIS) 3. For the evaluation phase, she administered a test for assessing students' understanding about law of definite proportions and a concept cartoon for assessing students understanding about nature of science. (Lesson Plan #2) (KoA) 4. I learned that I can use various methods to assess students' understanding about nature of science. Concept cartoons and concept maps are two of them. (reflection paper #4) (KoA)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	✓						
KoA	✓				✓		
KoIS	✓						
STO	✓						

✓ = present, O=absent; grey= missing data

Post-Intervention PCK for NOS Profile





Concept Cartoons used by Nurdan in her lesson plan to evaluate NOS aspects she addressed

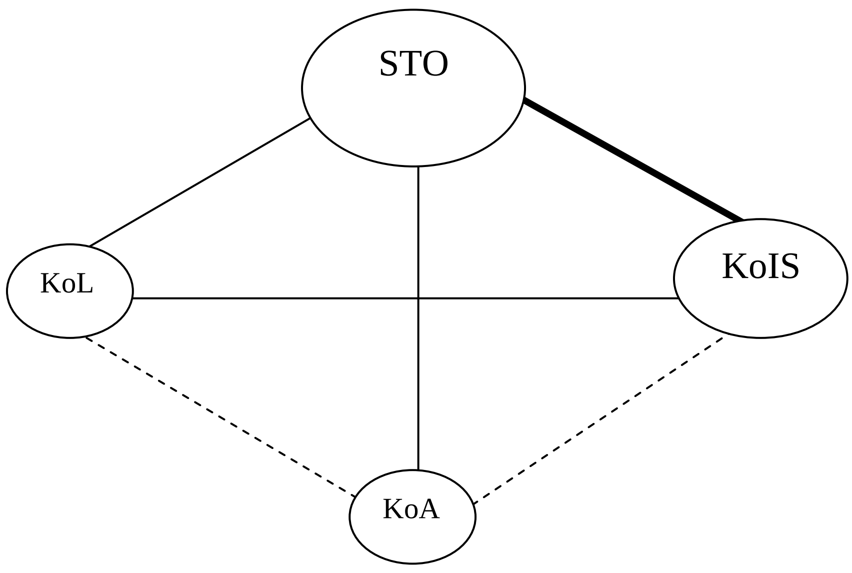
Profile of Participant 25	
Participant	Ozgun
Topic	Chemical Equilibrium
Science Teaching Orientation	• Correct explanation • Everyday Coping/Understand world • A structure of science • Scientific skill development-manipulative
SPS Objectives	• Experimenting • Communicating • Relating • Predicting • Observing • Data recording and interpretation • Comparing • Inferring
NOS objectives	the nature and role of model in science
Instructional Strategy	5E (inquiry) implicit
Lesson Synopsis	Ozgun used 5E model in her lesson planning. In the engagement phase, she gave several examples of static (scale) and dynamic (observing a bus moving to the opposite direction at the same speed with the bus which you are in) equilibrium from daily life using question-answer method and then asked students' ideas about chemical equilibrium. In the exploration phase, Ozgun had their students to design an investigation in groups of three to explore their ideas on whether chemical reactions reach equilibrium. She provided students the materials (HCl, NaOH, and K_2CrO_4 solutions, and test tubes). Throughout the exploration phase, Ozgun guided her students with the questions and also, asked them to write their observations, inferences, and then at the end present what they did and what they came up with as a result of their investigation. In the explanation phase, She conducted a whole class discussion on dynamic nature of chemical equilibrium and how the equilibrium is established. In the extend phase, she asked students to model what is happening in microscopic level before equilibrium, during equilibrium, and after equilibrium for $I_{2(g)} \longleftrightarrow 2I_{(g)}$. For designing of the model, she provided Erlenmeyer, cork, and molecule models to the students. At the end each group presented their model to the class and each model was discussed as a class. In the evaluation phase, Ozgun administered diagnostic tree to assess how deeper students understand the topic.
Evidence for the components of PCK and connections among them	1. In the extend phase, she asked students to model what is happening in microscopic level before equilibrium, during equilibrium, and after equilibrium for $I_2(g) \longleftrightarrow 2I(g)$. For designing of the model, she provided Erlenmeyer, cork, and molecule models to the students. At the end each group presented their model to the class and each model was discussed as a class. (Lesson Plan #2) (KoIS) 2. I eliminated my misconceptions in this lesson. I do not want that my future students to have misconceptions like I do. I will communicate adequate understanding about nature of science to my

students so that they will not have misconceptions. (Reflection paper #2) (STO)
3. Until now, we have not been taught about nature of science. Therefore, I was having lots of misconceptions about science. In my future chemistry teaching, I will teach both chemistry and nature of science (Reflection paper #3) (STO)
4. I can use similar instructional strategies that we saw throughout this lesson. That is, I teach nature of science embedded in chemistry content. Moreover, I will design activities where students will be active. (Reflection paper #5) (KoIS)
5. One of the difficulties that I can face with when designing my instruction is students' misconceptions about nature of science. I should consider these misconceptions and design an instruction that eliminate them. (Reflection paper #5) (KoL, KoIS)
6. Before this assessment lesson, I was thinking that it is hard to teach and assess both chemistry and nature of science at the same time. In this lesson, I realized that it is not as hard as I think. I learned various methods for assessing students' understanding of nature of science. (Reflection paper #4) (KoA)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	O					✓	
KoA	O				✓	O	
KoIS	✓					✓	
STO	✓		✓	✓		✓	

✓ = present, O=absent; grey= missing data

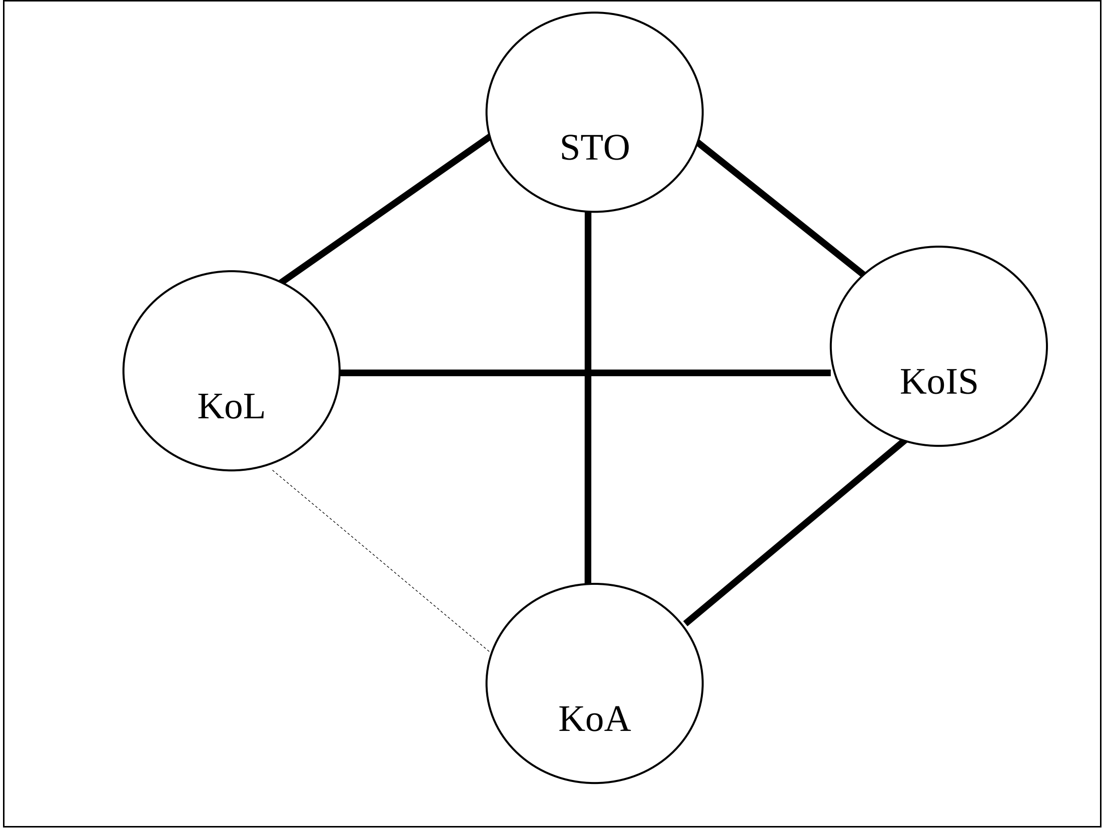
Post-Intervention PCK for NOS Profile



Profile of Participant 26	
Participant	Ozlem Tarım (Oya)
Topic	Affect of Concentration on Rate of Chemical Reactions
Science Teaching Orientation	• Everyday Coping/Understand world • A structure of science • Scientific skill development • Science, technology and society decisions
SPS Objectives	• Observing • Recording data • Data interpretation • Measuring • Predicting • Inferring • Classifying • Defining variables • Hypothesizing • Experimenting • Controlling variables • Reaching a conclusion
NOS objectives	The myth of universally accepted and step by step scientific method; subjectivity and the role of creativity and imagination in science
Instructional Strategy	Inquiry, explicit-reflective content embedded approach
Lesson Synopsis	Oya divided students into groups and asked students design an investigation to explore the effect of concentration on rate of reaction by providing the materials (0,002 M KIO_3 and 0,002 M $NaHSO_3$ solutions, beaker, Erlenmeyer, Bunsen burner, purified water, and chronometer) and to propose an explanation about the relationship between concentration and rate of reaction. After students completed their investigations, each group presented their investigation process, what they did and what they found. Then, Oya conducted a whole class discussion on the effect of concentration on rate of reaction and an explicit reflective discussion on the myth of universally accepted and step by step scientific method; subjectivity and the role of creativity and imagination in science by asking the questions of "How did you investigate the effect of concentration on rate of reactions?, What did you do throughout your investigation?, Did you follow a specific and step by step method throughout your investigation?, Did each member of the group and each group make some observations and reach the same conclusions?, and What causes the differences?" As an evaluation, she asked students to interpret a concept cartoon about rate of reaction and also, she asked students to prepare a poster indicating the application of their understanding of nature of science in their investigation process.
Evidence for the components of PCK and connections among them	1. At the end of the lesson, students will be able to understand a. that there is no universally accepted and step by step scientific method. b. the subjectivity in science c. the role of creativity and imagination in science (Lesson Plan #2, objectives, Oya) (STO, KoL) 2. After students completed their investigations, each group presented their investigation process, what they did and what they found. Then, Oya conducted a whole class discussion on the effect of concentration on rate of reaction and an explicit reflective discussion

	on the myth of universally accepted and step by step scientific method; subjectivity and the role of creativity and imagination in science by asking the questions of "How did you investigate the effect of concentration on rate of reactions?, What did you do throughout your investigation?, Did you follow a specific and step by step method throughout your investigation?, Did each member of the group and each group make some observations and reach the same conclusions?, and What causes the differences?" (Lesson Plan #2) (KoIS) 3. As an evaluation, she asked students to interpret a concept cartoon about rate of reaction and also, she asked students to prepare a poster indicating the application of their understanding of nature of science into their investigation process. (Lesson Plan #2) (KoA) 4. I had similar misconceptions about science as high school students have. I learned that what I should pay attention when designing my instruction in order to eliminate students' misconceptions about science. (Reflection paper #2) (KoL) 5. I realized the difference between implicit and explicit-reflective approach and also the effectiveness of explicit-reflective approach embedded in chemistry content when teaching nature of science. Before this lesson, I was thinking that it is hard to teach both chemistry and nature of science in the same lesson hour. I realized that it does not require too much time. (Reflection paper #3) (KoIS) 6. Before the lesson on scientific literacy and swine flu, I did not think that nature of science is something that I should teach. After that lesson, I decided that I should teach about science to all of the students not to just ones who want to become scientists. That lesson was a turning point for me. (post interview) (STO) 7. One of the difficulties that I may encounter when designing my instruction is students' misconceptions on nature of science. For instance; the hierarchical relationship between theories and laws and the universal and step by step scientific method. (post interview) (KoL) 8. Before the assessment lesson, I would ask direct questions to assess students' understanding about nature of science such as what is theory?, what is law. After the assessment lesson, I learned different ways of assessment. I can ask students to prepare a poster where they should present their investigation relating with their understanding about nature of science. (post interview) (KoA)

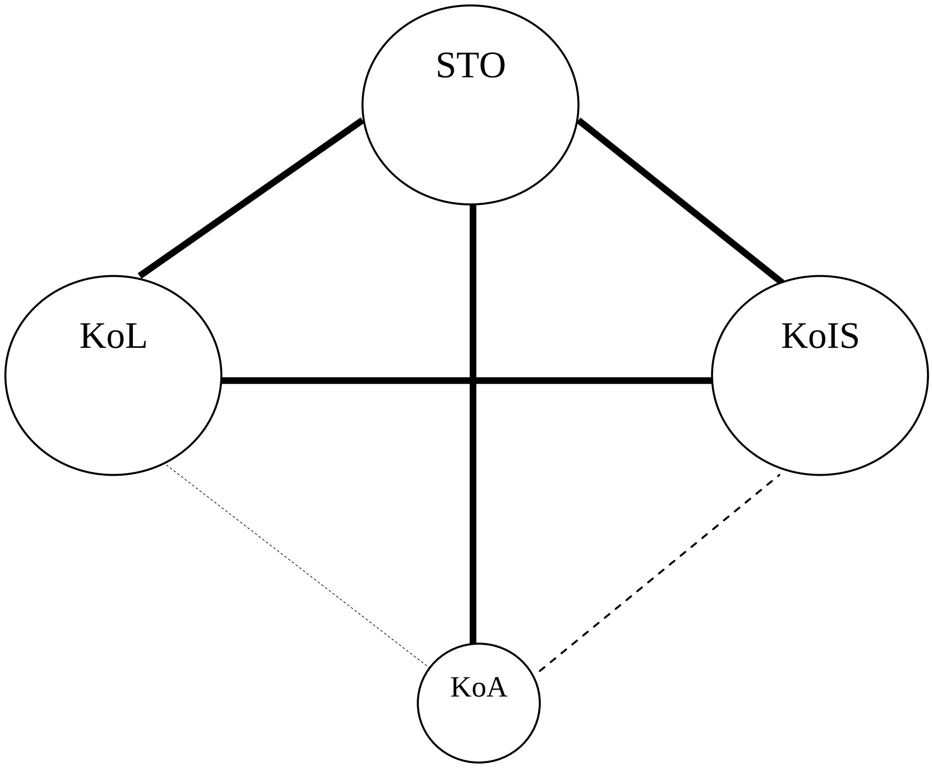
	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	✓		✓			✓	✓
KoA	✓				✓	✓	✓
KoIS	✓			✓		✓	✓
STO	✓	✓				✓	✓
✓ = present, O=absent; grey= missing data							
Post-Intervention PCK for NOS Profile							



Profile of Participant 27	
Participant	Ozden
Topic	Radoactivity
Science Teaching Orientation	• Science, technology and society decisions • Everyday Coping/Understand world • Correct Explanation • A structure of science
SPS Objectives	Absent
NOS objectives	The myth of experiments are the principal routes to scientific knowledge
Instructional Strategy	Case-based, Explicit-reflective approach
Lesson Synopsis	Ozden used snowball technique at the beginning of the lesson to elicit students' ideas on radioactivity. She asked students to write what comes to their mind on papers she distributed when they think about radioactivity. After students wrote their ideas they threw the papers each other like snowballs. Then, Ozden selected some of the students to read what is written on them. She conducted a whole class discussion on "Is radiation dangerous?" and after the discussion she explained what radiation is, types of radiation (e.g., radio waves, microwaves, infrared, visible light), and ionizing and non-ionizing radiation. After the explanation, Ozden read an article from Science and Technique magazine. This article was on the discovery of a new star and what scientists did throughout this discovery. She conducted an explicit-reflective discussion on the reading by asking the questions of "How did astronomers study?, What got your attention in the article?, Were they able to conduct any experiment throughout the process?, and Is experiment always possible and required in all scientific disciplines?" Ozden communicated that experiments are not the only routes to scientific knowledge. The article also was including the usage areas of radioactive isotopes She asked students those areas and then divided students in groups for having them discuss on the usage of radioactive isotopes. Each group presented their ideas to the class and then Ozden gave information about the usage of radioactive isotopes in medical, industry and science for tracking purposes using power point presentation. At the end of the lesson, she made a summary about the concepts emphasized throughout the lesson and distributed students different usage areas of radioactivity for having them prepare and present a poster. For the evaluation, she preferred to monitor students throughout the process by looking at students' participation in class and group activities.
Evidence for the	1. At the end of the lesson, students will be able to understand a. that experiments are not the only route to scientific

components of PCK and connections among them	knowledge (Lesson Plan #2, objectives, Ozden) (STO, KoL) 2. After the explanation, Ozden read an article from Science and Technique magazine. This article was on the discovery of a new star and what scientists did throughout this discovery. She conducted an explicit-reflective discussion on the reading by asking the questions of "How did astronomers study?, What got your attention in the article?, Were they able to conduct any experiment throughout the process?, and Is experiment always possible and required in all scientific disciplines?" Ozden communicated that experiments are not the only routes to scientific knowledge. (Lesson Plan #2) (KoIS) 3. Before this lesson, I was thinking that I should teach chemistry on a conceptual and daily life basis. But hereafter I will integrate nature of science into my teaching and help my students to have an adequate understanding about nature of science. (Reflection paper #1) (STO) 4. I learned what kind of misconceptions students may have about nature of science (e.g., hierarchical relationship between theories and laws) and why they think about science so. In my future chemistry teaching, I should be careful for not leading to a misconception in students' mind and provide students with the opportunities where they can explicitly discuss about science. (Reflection paper #2) (KoL, KoIS) 5. Students' previous ideas direct my teaching. Their misconceptions on both chemistry and nature of science identify the direction of my teaching. Since it will take more time to eliminate misconceptions about nature of science, I will communicate the same aspect in more than one lesson. (Reflection paper #5) (KoL, KoIS) 6. Nature of science is not something that students are able to learn by themselves using implicit methods. Students should reflect on their experiences from the perspective of science in an explicit way. I can easily integrate nature of science into my teaching without doing a huge revision in my teaching and I do not have to use strategies new to me. (Reflection paper #3) (KoIS) 7. For the evaluation, she preferred to monitor students throughout the process by looking at students' participation in class and group activities. (Lesson Plan #2) (KoA)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	✓		✓			✓	
KoA	✓					O	
KoIS	✓		✓	✓		✓	
STO	✓	✓				✓	
✓ = present, O=absent; grey= missing data							
Post-Intervention PCK for NOS Profile							



Profile of Participant 28	
Participant	Serhat
Topic	Acids and Bases
Science Teaching Orientation	• Everyday Coping/Understand world • A structure of science • Self as explainer
SPS Objectives	Absent
NOS objectives	Tentativeness; subjectivity and the role of creativity and imagination in science
Instructional Strategy	History of science, explicit-reflective content embedded approach
Lesson Synopsis	Serhat asked his students to investigate acid and base concepts proposed throughout the history. For the class, he prepared an activity sheet where he explained Arhenius, Bronsted-Lowry and Lewis acid base theories. Also, there were several questions to elicit students' understanding about nature of science; "Which one of the acid-base definition is true? and Why?, Why do scientists propose different explanations even though they are studying on the same data and same topic?, and Can scientific knowledge change in time?" After students studied on the activity sheet, he conducted a whole class discussion on acid-base theories and an explicit-reflective class discussion on tentativeness; subjectivity and the role of creativity and imagination in science by asking the questions of "Which one of the acid-base definitions is true? and Why?, Why do scientists propose different explanations even though they are studying on the same data and same topic?, What are the factors that explain the existence of more than one explanation on the same topic?, and Can scientific knowledge change in time?" As an assessment, he asked students to draw a concept map considering what they learned about acids-bases and nature of science.
Evidence for the components of PCK and connections among them	1. At the end of the lesson, students will be able to understand a. tentative nature of scientific knowledge b. subjectivity in science c. the role of creativity and imagination in science (Lesson Plan #2, objectives, Serhat) (STO) 2. For the class, he prepared an activity sheet where he explained Arhenius, Bronsted-Lowry and Lewis acid base theories. Also, there were several questions to elicit students' understanding about nature of science; "Which one of the acid-base definition is true? and Why?, Why do scientists propose different explanations even though they are studying on the same data and same topic?, and Can scientific knowledge change in time?" After students studied on the activity sheet, he conducted a whole class discussion on acid-base theories

and an explicit-reflective class discussion on tentativeness; subjectivity and the role of creativity and imagination in science by asking the questions of “Which one of the acid-base definitions is true? and Why?, Why do scientists propose different explanations even though they are studying on the same data and same topic?, What are the factors that explain the existence of more than one explanation on the same topic?, and Can scientific knowledge change in time?” (Lesson Plan #2) (KoIS)

3. As an assessment, he asked students to draw a concept map considering what they learned about acids-bases and nature of science. (Lesson Plan #2) (KoA)

4. I will integrate nature of science into my chemistry teaching and ny this way I will contribute to scientific literacy and students’ chemistry learning. (Reflection paper #1) (STO).

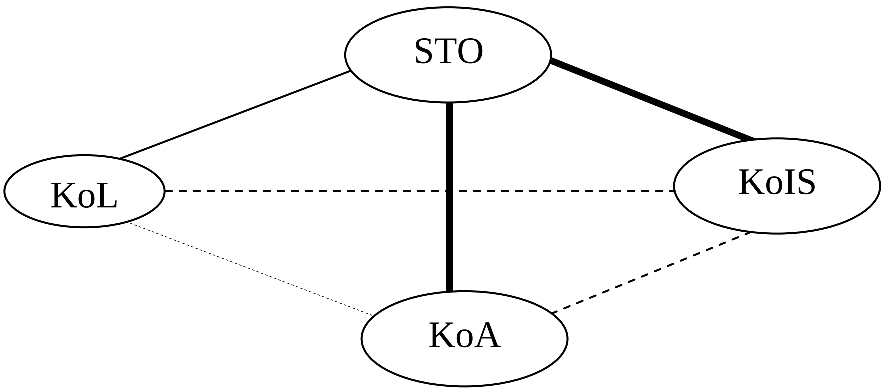
5. I learned that students may have various misconceptions in nature of science and these misconceptions should be eliminated. I realized that I should explain and teach theory and law concepts. If nature of science is not integrated into teaching, students may leave the instruction with misconceptions about nature of science. I will teach considering these points. (Reflection paper #2) (KoL, STO)

6. I can ask students to design a project, game, and to prepare a poster or concept map where they are expected to use nature of science concepts. (Reflection paper #5) (KoA)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	O		✓			✓	
KoA	✓				✓	✓	
KoIS	✓		✓			✓	
STO	✓	✓				✓	

✓ = present, O=absent; grey= missing data

Post-Intervention PCK for NOS Profile



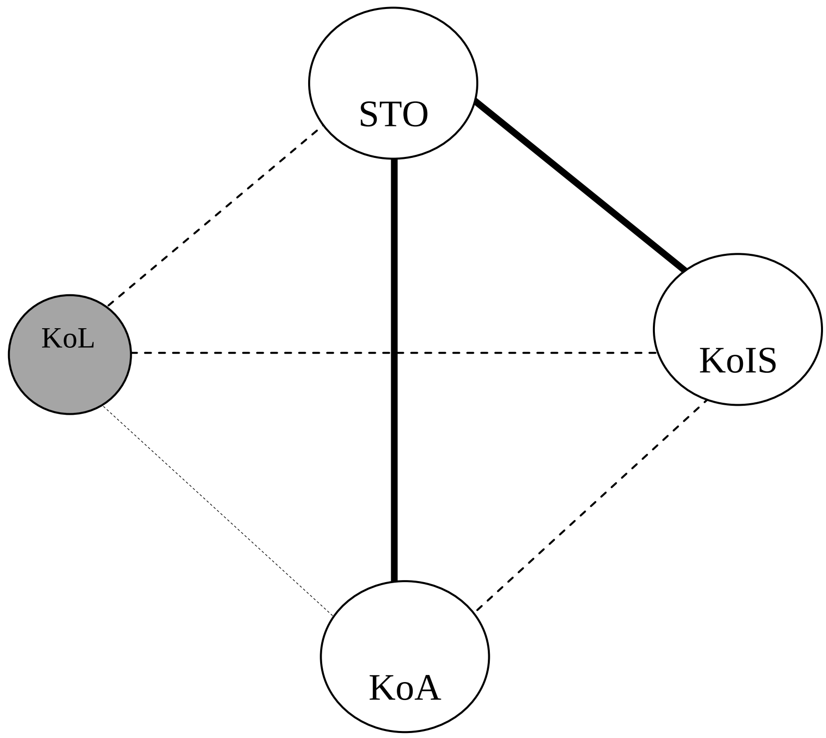
Profile of Participant 29	
Participant	Serap
Topic	Chemical Equilibrium
Science Teaching Orientation	• Everyday Coping/Understand world • Scientific skill development • A Structure of science • Science, technology and society decisions
SPS Objectives	Absent
NOS objectives	Empirical basis; observation; experiment; and the difference between observation and experiment
Instructional Strategy	5E (Inquiry) Explicit-reflective content embedded approach
Lesson Synopsis	Serap used 5E model in her lesson planning. For the engagement phase, she used an analogy. Summary of analogy is: Think of a bus with a 13-passenger capacity and it is forbidden to carry standing up passengers. The bus passed through seven stops and there have been several passengers getting off and getting on the bus. The bus started with no passenger and ended up with no passenger at the last stop. After telling the analogy, she asked her students whether they can relate the bus example to chemical equilibrium. If yes, what do passenger and bus represent? In the exploration phase, Serap asked students to design an investigation to explore whether chemical reactions reach equilibrium by providing the materials (0,1M $Co(H_2O)_6$ and 0,1M HCl solutions) and explaining the reactions between the two ($Co(H_2O)_{6(aq)}$ (PINK) + $4Cl^-_{(aq)}$ ↔ $CoCl_4^{-2}{}_{(aq)}$ (BLUE) + $6H_2O_{(l)}$). Also, she had her students to write their observations, investigation process in detail, and supporting or refuting evidences for their ideas. After completion of investigations, students presented their whole investigation process. In the explanation phase, Serap conducted a whole class discussion on chemical equilibrium and also an explicit-reflective discussion on empirical basis; observation; experiment; and the difference between observation and experiment by asking the questions of “What were your observations?, How did you observe?, What did you use for observations?, Did you make another thing except from observations throughout your investigations?, Did you made an experiment?, What is the difference between observation and experiment?, How can you be sure about the validity and reliability of your claims?, What makes us to believe you?” For the extend phase, she showed a simulation about chemical equilibrium and gave daily life examples to students (e.g., tooth decay, blood circulation in body). She administered a fill-the-gap test to assess students understanding about chemical equilibrium. For assessing nature of science, she

	asked students to interpret a case where they should use their knowledge about observation, experiment, and empirical basis. Another assessment for observations required students to use their knowledge of observations to decide whether a reaction reaches equilibrium or not.
Evidence for the components of PCK and connections among them	1. At the end of the lesson, students will be able to understand a. what observation is b. what experiment is c. the difference between observation and experiment d. empirical basis of science (Lesson Plan #2, objectives, Serap) (STO) 2. Serap asked students to design an investigation to explore whether chemical reactions reach equilibrium by providing the materials (0,1M Co(H2O)6 and 0,1M HCl solutions) and explaining the reactions between the two (Co(H2O)6(aq) (PINK) + 4Cl-(aq) ↔ CoCl4-2(aq) (BLUE) + 6H2O(l)). Also, she had her students to write their observations, investigation process in detail, and supporting or refuting evidences for their ideas. After completion of investigations, students presented their whole investigation process. In the explanation phase, Serap conducted a whole class discussion on chemical equilibrium and also an explicit-reflective discussion on empirical basis; observation; experiment; and the difference between observation and experiment by asking the questions of "What were your observations?, How did you observe?, What did you use for observations?, Did you make another thing except from observations throughout your investigations?, Did you made an experiment?, What is the difference between observation and experiment?, How can you be sure about the validity and reliability of your claims?, What makes us to believe you?" (Lesson Plan #2) (KoIS) 3. For assessing nature of science, she asked students to interpret a case where they should use their knowledge about observation, experiment, and empirical basis. Another assessment for observations required students to use their knowledge of observations to decide whether a reaction reaches equilibrium or not. (Lesson Plan #2) (KoA) 4. In this lesson, we learned how we can assess students' understanding of nature of science throughout and at the end of the lesson. I started to think that teaching about science is as much important as teaching science itself. (Reflection paper #4) (STO, KoA)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	O						
KoA	✓				✓		
KoIS	✓						
STO	✓				✓		

✓ = present, O=absent; grey= missing data

Post-Intervention PCK for NOS Profile



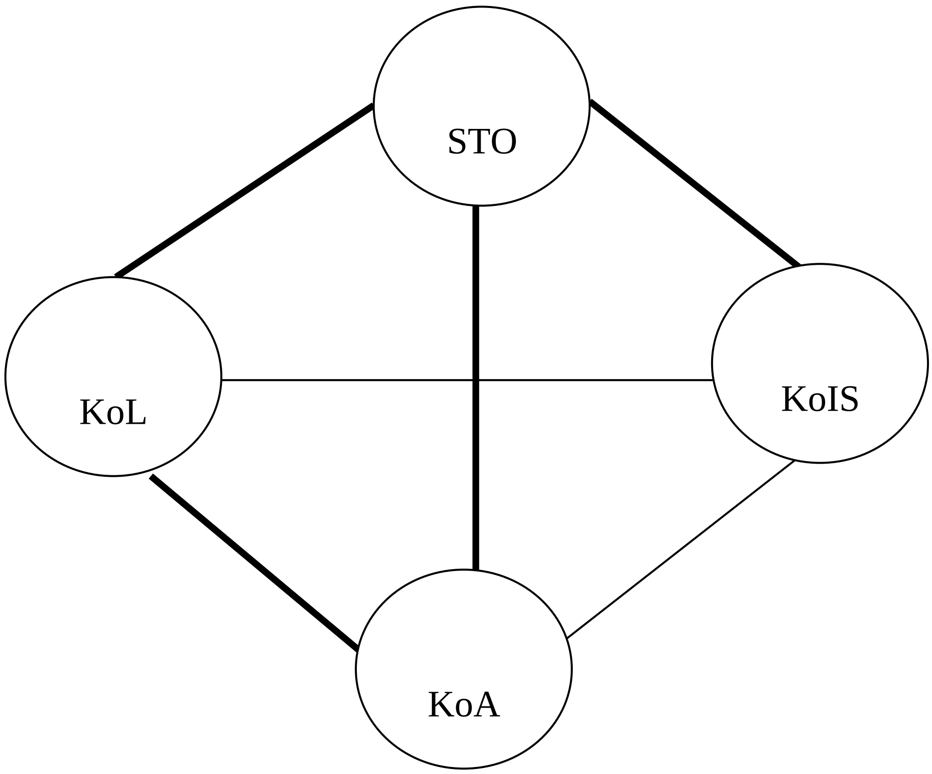
Profile of Participant 30	
Participant	Yasemin
Topic	Graham Diffusion Law
Science Teaching Orientation	• Everyday Coping/Understand world • A Structure of science • Correct explanation • Self as explainer • Improving attitudes towards science
SPS Objectives	Absent
NOS objectives	The nature of theory and law and the difference between them
Instructional Strategy	Guided-inquiry Explicit-reflective approach
Lesson Synopsis	Yasemin asked the assumptions of Kinetic Molecular Theory, which is the topic of the previous class, in order to remind previous knowledge to students using question-answer method. Then, she divided students into groups of four and asked to design an investigation to explore the factors affecting rate of diffusion of gases by providing the materials (glass pipe, HCl and NH_3 solutions, cotton, chronometer, and ruler). After completion of the investigations students presented their investigation and what they found about diffusion of gases. Then, Yasemin conducted a whole class discussion on Graham Diffusion Law and also conducted an explicit-reflective class discussion on the nature of theory and law by asking the questions "What does Graham diffusion tell about gases?, Does it describe a relationship or pattern?, What does kinetic molecular theory tell us about gases?, Does it describe a relationship or pattern too or does it explain the relationship or pattern described by laws? At the end, she asked students to draw a concept map for assessing students' understanding about nature of science and gases by providing the concepts (Kinetic Molecular Theory, Theory, Law, Graham Diffusion Law, Kinetic energy, gas molecules, molecular mass, and collision).
Evidence for the components of PCK and connections among them	1. At the end of the lesson, students will be able to understand a. what theory is b. what law is c. the difference between theory and law (Lesson Plan #2, objectives, Yasemin) (STO) 2. Then, she divided students into groups of four and asked to design an investigation to explore the factors affecting rate of diffusion of gases by providing the materials (glass pipe, HCl and NH_3 solutions, cotton, chronometer, and ruler). After completion of the investigations students presented their investigation and what they found about diffusion of gases. Then, Yasemin conducted a whole class discussion on Graham Diffusion Law and also conducted an explicit-reflective class discussion on the nature of

	theory and law by asking the questions “What does Graham diffusion tell about gases?, Does it describe a relationship or pattern?, What does kinetic molecular theory tell us about gases?, Does it describe a relationship or pattern too or does it explain the relationship or pattern described by laws? (Lesson Plan #2) (KoIS) 3. At the end, she asked students to draw a concept map for assessing students’ understanding about nature of science and gases by providing the concepts (Kinetic Molecular Theory, Theory, Law, Graham Diffusion Law, Kinetic energy, gas molecules, molecular mass, and collision). (Lesson Plan #2) (KoA) 4. I realized that while teaching chemistry concepts I should teach theory, law, what science is about, strengths and weaknesses of science, the difference between science and pseudoscience and etc.. That is I decided to integrate nature of science into my teaching. (Reflection paper #1) (STO) 5. I learned what kind of misconceptions students have about nature of science and what the sources of these misconceptions are. I will be a guide for my students when selecting the sources since each source does not communicate an adequate understanding of nature of science. When I teach chemistry, I will focus on nature of theory and law in order to help my students to understand these concepts. (reflection paper #2) (KoL) 6. If students have misconceptions about nature of science first of all these misconceptions should be eliminated. After eliminating the misconceptions other objectives related to nature of science are communicated since until the misconceptions eliminated students continue to hold misconceptions. (reflection paper #5) (KoL) 7. I learned that I should not use implicit approach when teaching nature of science since understanding nature of science is a cognitive objective. I realized that explicit reflective approach embedded in science content is an effective approach in nature of science teaching (reflection paper #3) (KoIS) 8. I realized that I should assess nature of science as well as chemistry. (Reflection paper #4) (KoA) 9. Concept maps, concept cartoons, case, and diagnostic tree can be used to assess students’ understanding of nature of science. I use these assessment methods to identify students’ misconceptions about science and then design instruction considering misconceptions (reflection paper #5) (KoL, KoIS, KoA)

	LP 2	R1	R2	R3	R4	R5	Interview
Description	After PCK for NOS	After STO	After KoL	After KoIS	After KoA	After PCK for NOS	After PCK for NOS
KoL	O		✓			✓	✓
KoA	✓					✓	✓
KoIS	✓					✓	✓
STO	✓	✓				✓	✓

= present, O=absent; grey= missing data

Post-Intervention PCK for NOS Profile



APPEDNDIX H

INSTUTIONAL REVIEW BOARD PERMISSION

EV. ARŞ. Md. Saat 8
ÖĞRENCİ İŞLERİ DAİRESİ BAŞKANLIĞI

T.C.
GAZİ ÜNİVERSİTESİ REKTÖRLÜĞÜ
(Öğrenci İşleri Dairesi Başkanlığı)

SAYI : B.30.2.GÜN.0.72.01.42/2475 - 8158 02../06/2010
KONU:

ORTA DOĞU TEKNİK ÜNİVERSİTESİ REKTÖRLÜĞÜNE
(Öğrenci İşleri Dairesi Başkanlığı)

İLGİ : a) 07/04/2010 tarih ve B.30.2.ODT.72.00.00/420-2515 - 5215 sayılı yazınız.
b) Üniversitemiz Gazi Eğitim Fakültesi Dekanlığı'nın 25/05/2010 tarih ve B.30.2.GÜN.0.12.72.01-2414 sayılı yazısı.

Üniversiteniz Ortaöğretim Fen ve Matematik Alanları Eğitimi EABD doktora programı öğrencisi Betül DEMİRDÖĞEN'in 5 Nisan – 26 Mayıs 2010 tarihleri arasında **"Bilimin Doğasının Öğretimi İçin Pedogojik Alan Bilgisinin Kazanılmasına Yönelik Öğretim Süresince Kimya Öğretmen Adaylarının Bilimin Doğasının Öğretimi İçin Pedagojik Alan Bilgilerinin Gelişimi"** konulu araştırması hakkındaki ilgi (a) yazınız Üniversitemiz Gazi Eğitim Fakültesi Dekanlığına iletilmiş olup; alınan cevabi ilgi (b) yazı ilişikte sunulmuştur.

Bilgilerinize arz ederim.

Prof.Dr.Duran ALTIPARMAK
Rektör Yardımcısı

Ek :
-İlgi (b) yazı (1 sayfa)

10.06.10 011051

O.D.T.Ü.
FEN BİLİMLERİ ENSTİTÜSÜ
YÖNETİM KURULU KARARI

Tarih: 01.04.2010
Sayı: FBE: 2010/18

GÖREVLENDİRME VE İZİN

Ortaöğretim Fen ve Matematik Alanları Eğitimi EABD doktora programı öğrencisi Betül Demirdöğen'in 05 Nisan-26 Mayıs 2010 tarihleri arasında "*Bilimin doğasının öğretimi için pedogojik alan bilgisinin kazanılmasına yönelik öğretim süresince kimya öğretmen adaylarının bilimin doğasının öğretimi için pedagojik alan bilgilerinin gelişimi*" başlıklı araştırmasına ilişkin hazırlanan anketi, Orta Doğu Teknik Üniversitesi ve Gazi Üniversites'inde uygulama yapmak için görevlendirilme başvurusu incelenmiş; ilgili danışman ve EABD görüşüne dayanarak adı geçen öğrencinin isteği doğrultusunda görevlendirilmesine oybirliği ile karar verilmiştir.

Prof. Dr. Canan Özgen
FBE Müdürü

Prof. Dr. Gürsevil Turan
FBE Müd. Yard.

Doç. Dr. Nil Uzun
FBE Müd. Yard.

Prof. Dr. Vedat Toprak
Üye

KATILAMADI

Doç. Dr. Ayşe Berkman
Üye

1956

Orta Doğu Teknik Üniversitesi
Middle East Technical University
Fen Bilimleri Enstitüsü
Graduate School of
Natural and Applied Sciences
06531 Ankara, Türkiye
Phone: +90 (312) 2102292
Fax: +90 (312) 2107959
www.fbe.metu.edu.tr

Sayı:B.30.2.ODT.O.40.O5.O2/126/1082

01.04.2010

GÖNDERİLEN: Doç. Dr. Belgin Ayvaşık
Rektör Danışmanı

GÖNDEREN : Prof.Dr.Gürsevil Turan
Fen Bilimleri Enstitüsü
Müdür Yardımcısı

KONU : Betül Demirdöğen hk.

Ortaöğretim Fen ve Matematik Alanları Eğitimi EABD doktora programı öğrencisi Betül Demirdöğen'in 05 Nisan-26 Mayıs 2010 tarihleri arasında "*Bilimin doğasının öğretimi için pedogojik alan bilgisinin kazanılmasına yönelik öğretim süresince kimya öğretmen adaylarının bilimin doğasının öğretimi için pedagojik alan bilgilerinin gelişimi*" başlıklı araştırmasına ilişkin hazırlanan anketi, Orta Doğu Teknik Üniversitesi ve Gazi Üniversites'inde uygulama yapmak için görevlendirilme başvurusu incelenmiş; ilgili danışman ve EABD görüşüne dayanarak adı geçen öğrencinin isteği doğrultusunda görevlendirilmesine Etik Komite onayı koşulu ile uygun görülmüştür.

Gereği için bilgilerinize saygılarımla sunarım.

Ek: EYK kararı ve ekleri

Etik Komite Onayı

Uygundur

01.04.2010

Prof.Dr.Canan Özgen
Uygulamalı Etik Araştırma
Merkezi (UEAM) Başkanı
ODTÜ 06531 ANKARA

T.C.
GAZİ ÜNİVERSİTESİ
GAZİ EĞİTİM FAKÜLTESİ DEKANLIĞI

SAYI : B.30.2.GÜN.0.12.72.01/ 2414
KONU : İzin

25 Mayıs 2010

GAZİ ÜNİVERSİTESİ REKTÖRLÜĞÜ
Öğrenci İşleri Dairesi Başkanlığına

İLGİ : 07.05.2010 tarih ve B.30.2.GÜN.0.72.01.42/2050-7668 sayılı yazınız.

Orta Doğu Teknik Üniversitesi Ortaöğretim Fen ve Matematik Alanlar Eğitimi EABD Doktora Programı öğrencisi Betül DEMİRDÖĞEN'in **"Bilimin Doğasının Öğretimi İçin Pedagojik Alan Bilgisinin Kazanılmasına Yönelik Öğretim Süresince Kimya Öğretmen Adaylarının Bilimin Doğasının Öğretimi İçin Pedagojik Alan Bilgilerinin Gelişimi"** başlıklı araştırmasını Fakültemiz Ortaöğretim Fen ve Matematik Alanlar Eğitimi Bölümü Kimya Eğitimi Anabilim Dalı öğrencilerine uygulama isteği, Anabilim Dalı Başkanlığı tarafından değerlendirilmiş olup; adı geçen doktora öğrencisinin söz konusu çalışmayı ders programı uygun olan öğretim elemanlarıyla görüşerek uygulaması Dekanlığımızca uygun görülmüştür.

Bilgilerinizi ve gereğini saygılarımla rica ederim.

M. Safran
Prof. Dr. Mustafa SAFRAN
DEKAN

Gazi Eğitim Fakültesi Dekanlığı 06500 Beşevler-ANKARA Telefon: (312) 202 80 90 - (312) 202 80 91 - (312) 202 80 92
Faks: (0 312) 223 86 93 e-posta: gef@gazi.edu.tr Elektronik Ağ: www.gef.gazi.edu.tr

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: DEMIRDÖĞEN, Betül

Nationality: Turkish (TC)

Marital Status: Single

Phone: +90 312 210 64 89

Fax: +30 312 210 79 71

e-mail: betuldemirdogen@gmail.com

EDUCATION

Degree	**Institution**	**Year of Graduation**
MS	Gazi University, Secondary Science and Mathematics Education	2004
BS	Gazi University, Secondary Science and Mathematics Education	2004
High School	Suleyman Demirel Anatolian High School	1999

FOREIGN LANGUAGES

English

FUNDED PROJECTS

1. Investigation of university students' chemistry self-efficacy with regard to different variables, Middle East Technical University, The Coordination of Scientific Research Projects, Prokect Number: BAP-2008-05-01-04, 2008, Researcher

2. Teaching the Nature of Science: Production of a professional development package for teaching scientific argumentation and reasoning based on philosophy and history of science, The Scientific and Technological Research Council of Turkey, Project Number:108K086, 2008-2011, Researcher
3. Cacabey Astronomy Camp, The Scientific and Technological Research Council of Turkey, Project Number:109B053, 2009, Instructor

PUBLICATIONS

A. Paper Published in Journals

Aydin, S., Demirdöğen, B., & Tarkin, A. (2012). Are they efficacious? Exploring pre-service teachers' teaching efficacy beliefs during practicum. *The Asia-Pacific Education Researcher, 21(1),* 203-213. (Indexed in SSCI)

Elmas, R., Demirdöğen, B., & Geban, Ö., (2011). Preservice chemistry teachers' images about science teaching in their future classrooms. *Hacettepe University Journal of Education*, 40: 164-175. (Indexed in SSCI).

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Yeşiloğlu, S. N., Demirdöğen, B., & Köseoğlu, F. (2010). The First Step in Nature of Science Teaching: New Society Activity and Arguments on Its Implemantation, *Ahi Evran University Journal of Kırşehir Education Faculty, 11(4),* 163-186.

Özdem, Y., Demirdöğen, B., Yeşiloğlu, N., & Köseoğlu, F. (2010). Development of Science Views Held By Teachers in Different Disciplines through Social Constructivist Approach, *Ahi Evran University Journal of Kırşehir Education Faculty*, *11(4)*, 263-292.

B. Papers Presented in International and National Conferences:

Demirdöğen, B., Elmas R. & Uzuntiryaki E. (2007). *An Analysis of Two 10th Grade Chemistry Textbooks On The Topic of Gases and Evaluating Them By Using Concept Maps*, Paper presented at the International Meeting On Critical Analysis Of School Science Textbook, 7-10 February, Hammamet, Tunuisia.

Demirdöğen, B., Çetin-Dindar, A., & Uzuntiryaki E. (2008). *Pre-Service Chemistry Teachers' Pedagogical Content Knowledge about The Particulate Nature Of Matter*. Paper presented at the 9th ECRICE - European Conference on Research in Chemical Education, 6-9 June, İstanbul, Turkey.

Demirdöğen, B., Çetin-Dindar, A., & Uzuntiryaki E. (2008). *What are the Pre-Service Chemistry Teachers' Conceptions about Particulate Nature Of Matter?* Paper presented at the 8th National Science and Mathematics Education Conference, 27-29 August , Bolu, Turkey.

Yerdelen Damar, S. & Demirdöğen, B. (2008). *Identifying Pre-service Physics Teachers' Mental Images about Themselves as Teachers.* Paper presented at the 8th National Science and Mathematics Education Conference, 27-29 August , Bolu, Turkey.

Elmas R., Demirdöğen, B., & Geban, Ö. (2008). *A Content Analysis of 6th and 7th Grade Science and Technology Textbook and 10th Grade Chemistry Textbook about Environmental Issues.* Paper presented at the 13th World Council for Curriculum and Instruction (WCCI) Conference, 2-7 September, Antalya, Turkey.

Demirdöğen, B. (2008). *To What Extend Science Teachers Reflect the Curriculum Changes.* Paper presented at the The European Conference on Educational Research, Göteborg, İsveç, 89-12 September, Gothenburg, Sweeden.

Demirdöğen, B., Uzuntiryaki, E., & Çapa Aydın, Y. (2009). *College Students' Use Of Learning Strategies And Their Anxiety Levels In Chemistry*. Paper presented at the National Association for Research in Science Teaching, 17-21 April, Garden Grove, CA, USA.

Demirdöğen, B., Uzuntiryaki, E., & Çapa Aydın, Y. (2009). *Freshmen Students' Chemistry Self-Efficacy In Relation To Goal Orientation, Gender, and Academic Achievement*. Paper presented at the National Association for Research in Science Teaching, 17-21 April, Garden Grove, CA, USA.

Aydın, S., Demirdöğen, B., Tarkın, A., & Uzuntiryaki, E. (2009). *Effectiveness of a Course on Pre-service Chemistry Teachers' Pedagogical Content Knowledge and Subject Matter Knowledge*. Paper presented at the European Science Education Research Association, 31 August- September 4, Istanbul, Turkey. (Fulltext was published in proceedings of ESERA, p. 59-69).

Yeşiloğlu, S. N., Demirdöğen, B. Köseoğlu, F. (2009). *Enhancing Prospective Teachers' Views on Nature of Science within a Social Context.* Paper presented at the European Science Education Research Association, 31 August- September 4, Istanbul, Turkey.

Tarkin, A., Demirdöğen, B., & Aydın, S. (2010). *Pre-service Chemistry Teachers' Self-Efficacy Beliefs.* Paper presented at the 9th National Science and Mathematics Education Conference, 23-25 September, İzmir, Turkey.

Köseoğlu, F., Demirdöğen, B., & Yeşiloğlu S.N. (2010). *Prospective teachers' reflective experience of nature of science through role playing a historical case.* Paper presented at the International Conference of Education, Research and Innovation, 15-17 November, Madrid, Spain.

Taşdelen U., Köseoğlu, F. Özdem, Y., & Demirdöğen B. (2010). *Interactive evaluation of nature of science: a taboo-like game as a final semester activity.* Paper presented at the International Conference of Education, Research and Innovation, 15-17 November, Madrid, Spain.

Demirdöğen, B. & Uzuntiryaki, E. (2011). *Development of Pre-service Chemistry Teachers' Pedagogical Content Knowledge for Teaching Nature of Science*. Paper presented at the National Association for Research on Science Teaching, 3-6 April, Orlando, FL, USA.

Demirdöğen, B. & Uzuntiryaki, E. (2012). *Development of Pre-service Chemistry Teachers' Pedagogical Content Knowledge for Teaching Nature of Science.* Paper presented at the National Association for Research on Science Teaching, 25-28 March, Indianapolis, IN, USA.

Tüysüz, M., Tarkın, A., Kutucu, E. S., Ekiz, B., Aydın, S., Demirdöğen, B., & Uzuntiryaki, E. (2012). *Pre-service chemistry teachers' views about the problems of chemistry education and their suggestions for solutions.* Paper presented in the 10th National Science and Mathematics Education Conference, 27-30 June, Niğde, TURKEY.

C. Poster Presentations in National and International Conferences

Aydin, S., Demirdogen, B., Muslu, N., & Hanuscin, D. (2011). *Professional articles as a source for pedagogical content knowledge for teaching nature of science.* Poster presented at the biannual meeting of the European Science Education Research Association (ESERA), 5-9 September, Lyon, France.

Aydın, S., Tarkın, A., & Demirdöğen, B. (2010). *Pre-service teachers' View about the Teaching Experience Course Enriched with Microteaching*. Poster presented in the 9th National Science and Mathematics Education Conference, 23-25 September, Izmir, TURKEY.

D. Mini-Symposiums in National and International Conferences

Nature of Science Professional Development Package for Pre- and In-service Teachers. 9th National Science and Mathematics Education Conference, 23-25 September 2010, İzmir, Turkey.

a. Taşdelen, U., Demirdöğen, B., Tümay, H., & Üstün, U. (2010). Nature of Science Professional Development Package for Pre- and In-service Teachers–Sample Activities I
b. Demirdöğen, B., Yeşiloğlu, S. N., & Köseoğlu, F. (2010). Nature of Science Professional Development Package for Pre- and In-service Teachers –Pedagogical Content Knowledge.

INSERVICE TRAININGS

24-26 June 2010, A Workshop on Nature of Science and Its Teaching, Gazi University, Ankara, Turkey.

14-16 September 2010, A Workshop on Nature of Science and Its Teaching, Hasan Ali Yücel Anatolian High School, Ankara, Turkey.

13 June 2012, Turkish Science Education Research Association Workshops I: Contemporary Developments and Applications in Science Curriculums. Marmara Üniversity, Atatürk College of Education.

AWARDS

National Asociation for Research in Science Teaching Scholarship Winner in 2012.

PROFESSIONAL MEMBERSHIP

National Association for Research in Science Teaching (NARST)

Turkish Science Education Research Association

National Science Teacher Association (NSTA)

NSTA Missouri Student Chapter

OTHER EXPERIENCES

1. Reviewer for Research in Science Education Journal (RISE) Journal in September, 2012.
2. Reviewer for National Association for Research in Science Teaching 2009.
3. Chair in 9th ECRICE - European Conference on Research in Chemical Education, 6-9 June, İstanbul, Turkey.
4. Grant Writing Experience:

   Grant Writing Group (Fall 2010) *Improving Teacher Quality Grants* –
   PI: Dr. Deborah Hanuscin, Co-PI: Dr. Delinda van Garderen

   Participated in weekly meetings leading up to the submission of a $472,000 grant for K6 science teacher professional development. Activities included reviewing and interpreting the RFP; attending sponsor technical assistance meetings; assisting in conceptualizing the PD; providing input on program design, evaluation, and budget; and conferring with the Office of Sponsored Programs.

HOBBIES

Playing tennis, going to gym, watching movies, and reading books