EXAMINATION OF INTERACTION BETWEEN PRE-SERVICE CHEMISTRY TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE AND CONTENT KNOWLEDGE IN ELECTROCHEMISTRY

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

ELIF SELCAN KUTUCU

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY
IN
SECONDARY SCIENCE AND MATHEMATICAL EDUCATION

SEPTEMBER 2016

Approval of the thesis:

EXAMINATION OF INTERACTION BETWEEN PRE-SERVICE CHEMISTRY TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE IN ELECTROCHEMISTRY

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ABSTRACT

EXAMINATION OF INTERACTION BETWEEN PRE-SERVICE CHEMISTRY TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE AND CONTENT KNOWLEDGE IN ELECTROCHEMISTRY

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September 2016, 173 pages

The purpose of this study was to examine the interaction between pre-service chemistry teachers' pedagogical content knowledge (PCK) and content knowledge (CK) while teaching electrochemistry. Two pre-service chemistry teachers enrolled in practice teaching course in chemistry education program. All PCK components were studied in the current study to examine participants' PCK. In order to get detailed information and understand deeply the interaction between CK and PCK, qualitative methodology was used and the participant were selected through purposeful sampling. Data were collected through electrochemistry content test, Content Representation (CoRe), semi-structured interviews, stimulated recall interviews, classroom observations and field notes. Results indicated that CK and PCK were correlated knowledge bases but they are distinct and there is no direct proportional correlation between them. In other words, basic level of CK is a prerequisite for developing PCK, while a high CK does not affect a high PCK to the same extent. Pre-service teachers with weak content knowledge had problems in recognizing students' possible misconceptions, using vertical and horizontal relations in the curriculum and using the topic specific instructional strategies effectively. The level of content knowledge did not have strong impact on choices of subject specific instructional strategies, how to assess students' understanding, science teaching orientations of pre-service teachers.

Teacher education programs should focus on activities that improving both content knowledge and pedagogical content knowledge of pre-service teachers.

Keywords: Pedagogical Content Knowledge, Content knowledge, Pre-service teachers, Electrochemistry

ÖZ

ÖĞRETMEN ADAYLARININ ELEKTROKİMYA KONUSUNDA PEDAGOJİK ALAN BİLGİSİ VE KONU ALAN BİLGİLERİ ARASINDAKİ İLİŞKİNİN İNCELENMESİ

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Eylul 2016, 173 sayfa

Bu çalışmanın amacı kimya öğretmen adaylarının pedagojik alan bilgilerinin (PAB) ve kimya alan bilgilerinin elektrokimya konusunu öğretirken nasıl etkileştiğini araştırmaktır. Kimya öğretmenliği programındaki öğretmenlik uygulamaları dersine kayıtlı 2 tane kimya öğretmen adayı ile çalışılmıştır. Çalışma kapsamında PAB tüm alt bileşenleri çalışılmıştır. PAB ve kimya alan bilgisi arasındaki ilişkiyi daha iyi anlamayabilmek ve derinlemesine bilgi edinebilmek için nitel araştırma yöntemi kullanılmış ve katılımcılar amaçlı örneklem yöntemi ile seçilmiştir. Veriler, elektrokimya konu alan testi, içerik gösterimi, yari yapılandırılmış görüşmeler, sınıf gözlemleri ve gözlem notları ile toplanmıştır. Sonuçlar konu alan bilgisinin ve pedagojik alan bilgisinin bağlantılı bilgi türleri olduğunu ancak aralarında doğrusal orantılı bir ilişki olmadığını göstermiştir. Diğer bir deyişle öğretmenin pedagojik alan bilgisinin gelişebilmesi için belli bir seviyede alan bilgisine ihtiyaç vardır, ancak iyi seviyedeki alan bilgisi aynı oranda iyi bir pedagojik alan bilgisini garanti etmez. Alan bilgisinde eksiklikler olan öğretmen adayının öğrencilerin sahip olabileceği kavram yanılgılarını belirlemesinde, müfredattaki konu bağlantılarını yapmasinda ve konuya özgü öğretim stratejilerini etkili kullanmasinda zorluklar yaşadığı tespit edilmiştir. Konu alan bilgi seviyesindeki değişikliklerin öğretmen adaylarının alana özgü öğretim stratejilerinin seçiminde, öğrencilerin anlama bilgisini ölçmek için strateji belirlenmesinde ve fene karşı yönelimlerinde etkisi olmadığı görülmüştür. Bu çalışmanın sonuçları öğretmen eğitimi programlarının öğretmen adaylarının hem konu alan bilgisini hem de pedagojik alan bilgilerini geliştirmeye odaklanmalı ve buna uygun eğitimler verilmesi gerektiğini ortaya koymuştur.

Anahtar kelimeler: Pedagojik alan bilgisi, konu alan bilgisi, kimya öğretmen adayları, elektrokimya

To my parents and my brother,

ACKNOWLEDGMENTS

I would like to thank my advisor, Prof. Dr. Yezdan BOZ, for her special support and motivation for conducting this research. You are always kind and helpful to me. You provided feedback with endless energy and guided me throughout my doctorate. Thank you very much.

Besides my advisor, I would like to thank committee members, Prof. Dr. Jale ÇAKIROĞLU, Prof. Dr. Esen UZUNTİRYAKİ KONDAKÇI, Prof. Dr. Ayhan YILMAZ and Assoc. Prof. Dr. Hüseyin AKKUŞ. Thank you very much for your valuable feedback, insightful comments and suggestions to make my research much better and richer.

I wish to express my thanks to the members of Mathematics and Science Education Department of University of Georgia as well, especially Prof. Dr. Julie Anne LUFT and Prof. Dr. Steve OLIVER. Throughout my visiting year in university of Georgia (UGA), you helped me a lot about my research. With your support, feedbacks and ideas, I improved my way thinking in terms of science education research. Thank you very much.

My sincere thanks also goes to Prof. Dr. Ömer GEBAN, the head of SSME department, for his kindness, encouragement and behaving us as a special member of SSME family. I was always feel myself as a part this big family.

I also want to thank to my special friends who are Betül EKİZ KIRAN, Sinem ÜNER, Ayşegül TARKIN, and Sevgi AYDIN and all friends in the SSME department. Thank you for your support and feedback during instrument development, data collection and data analysis.

I also want to thank to my special and close friends; Sabiha SUNAR, Nilgün DEMİRCİ CELEP, Sinem ÜNER, Funda ALPTEKİN, Büşra TUNCAY YÜKSEL, Özge KAZAK TOPRAKTAN and Dekant KIRAN for being always there as true friends. They have always supported and encouraged me with their guidance, patience and love throughout the doctorate. Also special thanks goes to Serra ALTINOLUK and Ömer ATAŞ. They always supported and helped with patience and understanding throughout the last days of doctorate. I would also like to thanks my friends met in Athens, Georgia, USA. Bahadir NAMDAR, Hakan İSLAMOĞLU, Gülden ÇINAR and Oğuz MÜLAYİM. I had a great year in Athens with you. Thank you all for being my part of life and will be.

I also thank to my close friend Betül EKİZ KIRAN for your friendship and support. I am grateful for being a part of my life, being both a close friend and sister to me. We shared both joy and troubles together throughout the doctorate.

I would like to thank to my great family. I am really thankful to my mother, Filiz KUTUCU and my father, Sadik KUTUCU who did their best to raise us as an honest, hardworking and good person. My brother, Serdar KUTUCU also deserved special thanks. You are with me whenever I need you. I feel really lucky for being a part of this lovely family. Thank you for supporting me throughout my life. Also, my cousin Füsun AKMAN TAŞKESEN deserves very special thanks for her kindness and support. You have a special place in my life.

Finally, I want to thank TÜBİTAK (The Scientific and Technological Research Council of Turkey) for financial support during the PhD with through the program coded as BIDEP-2211. Also, I would like to thank the Higher Education Council for giving me the chance of visiting University of Georgia through the Study Abroad Scholarship Program. Finally, special thanks to the program (ÖYP) that I enrolled to.

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LIST OF ABBREVIATIONS

PCK:	Pedagogical Content Knowledge
CK:	Content Knowledge
CoRe:	Content Representation
PaPeRs:	Professional and Pedagogical experience Repertoire
NOS:	Nature of Science
SHE:	Standard Hydrogen Electrode
R:	Researcher
KoAs:	Knowledge of Assessment
KoL:	Knowledge of Learner
KoC:	Knowledge of Curriculum
KoIS:	Knowledge of Instructional Strategy

CHAPTER 1

INTRODUCTION

In recent years, there is an increasing interest in general aspects of teaching and learning science (Van Driel, De Jong & Verloop, 2002). In this issue, teachers have an essential role so teachers need to develop their skills and knowledge in many domains such as content knowledge, general pedagogical knowledge and pedagogical content knowledge to have an effective role in classrooms and schools (Boz & Boz, 2008; Canbazoglu, Demirelli, & Kavak, 2010; Goodnough & Hung, 2009; Van Driel et al., 2002). In other words, it is crucial for teachers to improve their theoretical and practical knowledge and abilities about teaching to improve their teaching quality. In order to improve the qualifications of teachers, before all else, as educators we ought to discover general and specific qualifications that teachers should have and help pre-service teachers gain these qualifications in teacher education programs. Sharon Feiman-Nemser (2001) defined learning to teach as a life-long learning process from beginning to pre-service teacher education, through beginning teacher to participation in professional teacher community. From this point, in teacher education programs pre-service teachers should gain these abilities and knowledge, hence pre-service teachers' PCK can affect the quality of their teaching and their future students' achievement (Gess- Newsome, 1999).

In teacher education field, a body of research was conducted about pre-service teacher knowledge about teaching science (Aydin, Demirdogen,Tarkin, Kutucu, Ekiz, Akin, Tuysuz & Uzuntiryaki, 2013; De Jong, Van driel & Verloop, 2005; Mellado, 1998), how to develop their teaching, PCK (Beyer & Davis, 2012; Brown, Friedrichsen & Abell, 2013; Loughran, Mulhall & Berry, 2008; Hume & Berry, 2011; Van Driel et al., 2002) and the interaction between their PCK and other constructs as CK (Kaya, 2009; Käpylä, Heikkinen, & Asunta, 2009). Shulman (1987) introduced pedagogical content knowledge (PCK) as ''…that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding’’ (p.8). In other words, content knowledge and using of pedagogical knowledge in terms of instructional practices, educational objectives, knowledge of learners, knowledge of assessment techniques, classroom management were accumulated in one construct namely pedagogical content knowledge (PCK) (Magnusson, Krajcik, & Borko, 1999; Sande, 2010). In the present study, pre-service teachers’ knowledge about teaching and the interaction between PCK and CK were focused.

Shulman (1987) described ‘’the knowledge base for teaching’’ as the knowledge that teacher should possess and it includes PCK. This knowledge base includes seven categories namely content knowledge, PCK, curriculum knowledge, learners and their characteristics, educational contexts, and educational purposes. In this second article, Shulman described PCK as a category on its own not as a subcategory as described in the article in 1986. Some other scholars were extended the Shulman’s model by adding some of the categories of knowledge over time (Hashweh, 2005; Magnusson et al., 1999; Tamir, 1988). Magnusson, Krajcik and Borko (1999) described pedagogical content knowledge as transformation process ‘‘of several types of knowledge for teaching’’ (p. 95). According to Magnusson et al. (1999), PCK was composed of five components: (a) orientation toward science teaching, (b) knowledge of science curriculum, (c) knowledge of science assessment, (d) knowledge of students’ understanding, and (e) knowledge of instructional strategies. In this study, Magnusson et al. 1999 PCK model was used.

1.1 Significance of the Study

Content knowledge (CK) and pedagogical content knowledge (PCK) are viewed as crucial knowledge domains of teachers’ professional knowledge in the related literature (Abell, 2007; Jüttner, Boone, Park & Neuhaus, 2013). PCK is thought to be a special body of knowledge, a blend of content knowledge and pedagogy that teachers should have for effective teaching (Shulman, 1987). There have been many knowledge domains that contribute to effective teaching, but researchers have drawn attention to content knowledge (Kind, 2009b; Magnusson et al., 1999). Research studies have emphasized that having deep understanding of science content knowledge plays important role in improving and changing teachers' instructional practices (Halim & Meerah, 2002; Hashweh, 1987; Van Driel, Verloop & De Vos, 1998; Van Driel et al., 2002). On the other hand, researchers have also emphasized that having good content knowledge is not sufficient for effective teaching (Abell, 2007; Fischer, Borowski & Tepner, 2012; Kind, 2009a), and Mapolelo (1999) stated that strong content knowledge does not lead to improvement of PCK. Thus, there is some controversy among researchers about the role of content knowledge in teaching performance. Therefore, researches indicated that both having content knowledge and pedagogical content knowledge play crucial role on how teachers teach but the relation between these two construct is not clear.

In the related literature, there have been studies that investigate the relation between CK and PCK, (Kaya, 2009; Käpylä et al. 2009; Kind, 2009a, Sanders, Borko, & Lockard, 1993), the outcomes of these studies are contradictory. For instance, Kaya (2009) conducted a quantitative study with 216 pre-service teachers and found that participants having good content knowledge had a tendency to have rich PCK. On the other hand, Kind (2009a) compared trainees in and out of field and found that trainees while teaching out of their field they teach more effectively. So lack of content knowledge trigger pre-service teachers to work hard and improve their teaching. Also, in a review on pedagogical content knowledge in science education, Kind (2009b) mentioned about the debate on the relation between CK and PCK. The review indicated that there is no consensus how they are related and how PCK interacts with CK. Hence, there is a great need to determine how content knowledge impacts their practical knowledge for teaching, namely pedagogical content knowledge. The relationship between content knowledge and PCK needs further research (Käpylä et al., 2009).

Furthermore, PCK literature calls for research using new methods in addition to interview, observation, Content representation (CoRe), and Pedagogical and Professional-experience Repertoires (PaP-eRs) to capture teacher' PCK while teaching (Abell, 2008). Also, in a recent book chapter, Henze and Van Driel (2015) mentioned that there have been studies in order to relate teachers' verbal articulation of PCK to actual classroom behavior, however the relationship between teachers' PCK as investigated through interview and their teaching practice, is not straightforward. Henze and Van Driel (2015) proposed an option as utilizing stimulated recall interviews as a way of use to gain point of view regarding the knowledge that teachers actually use during enactment of their instruction hence "teachers obviously cannot think aloud while teaching, stimulated recall is a technique that asks teachers to comment on a video of teaching. The idea is not to ask teachers to justify what they did, but to reconstruct their thinking while they were teaching." (Henze & Van Driel, 2015, p.132) In this study, video stimulated recall interview was used to lead pre-service teachers to think aloud pertained to their classroom teaching and access the relationship between pre-service teachers' PCK and CK.

As known, PCK development is an ongoing process and the first step for PCK development is pre-service teacher education level. During teacher education programs, pre-service teachers are prepared for their entire careers as a teacher and they gain foundational knowledge and skills that will facilitate development of their PCK during teaching profession (Korthagen, Loughran & Russell, 2006). One of the prevailing factors contributing teachers' PCK development is science content knowledge (Van Driel et al., 1998; Nilsson, 2008; Park & Oliver, 2008). Many in-service and pre-service teachers do not have adequate science content knowledge about the subject they are teaching (Abell, 2007; McConnell, Parker & Eberhardt, 2013) and this lack of understanding of content knowledge prevents them from planning and enacting their instruction properly (Tepner & Witner, 2011). However, it can be changed "…if pre-service teachers were offered meaningful ways of defining, assessing and explicitly developing PCK" (Nilsson & Loughran, 2012, p.700). As it was known pre-service teachers have little PCK or they lack of PCK (Magnusson et al., 1999; Van Driel et al. 1998) due to lack of teaching experience compared to experience teachers (Nilsson, 2008). On the other hand, reflection is a crucial factor for pre-service teachers to develop teaching skills in their teaching practice and take more responsibility for their own actions (Magnusson et al., 1999; Nilsson, 2008; Park & Oliver, 2008). The powerful side of the present study is to collect data in the real classroom environment and give a chance to pre-service teachers to analyze, observe and reflect on their own classroom experiences. By this way both pre-service teacher and the researcher can understand the interaction between content knowledge and teaching, PCK.

Although there have been large scale correlational studies investigating the relationship between teachers' content knowledge and PCK with each other and with teaching practice (Kaya, 2009; Jüttner et al. 2013; Tepner & Dolly, 2014), little is known about how teachers' knowledge about a science topic (content knowledge) impacts their teaching (PCK) in qualitative nature. Furthermore, there is a need to investigate the relationship between pre-service teachers' content knowledge and pedagogical content knowledge while transforming their content knowledge into real classroom environment (Kaya, 2009).

Therefore, the purpose of this study is twofold: to identify pedagogical content knowledge of pre-service chemistry teachers on electrochemistry, and the second one is to investigate the interaction between pre-service chemistry teachers' PCK and content knowledge while teaching electrochemistry.

1.2 Research Questions

The main research questions of this study are:

How do pre-service chemistry teachers' content knowledge and pedagogical content knowledge interact including STO, KoL, KoIS, KoAs and KoC while teaching electrochemistry?

The sub-research questions of this study were:

1. What is pre-service chemistry teachers' content knowledge regarding electrochemistry?

2. What is the nature of pre-service chemistry teachers' PCK regarding electrochemistry?

a) What is nature of pre-service chemistry teachers' science teaching orientation regarding electrochemistry?
b) What is nature of pre-service chemistry teachers' knowledge of learner regarding electrochemistry?
c) What is nature of pre-service chemistry teachers' knowledge of instructional strategy regarding electrochemistry?
d) What is nature of pre-service chemistry teachers' knowledge of curriculum regarding electrochemistry?
e) What is nature of pre-service chemistry teachers' knowledge of assessment regarding electrochemistry?

3. How do pre-service chemistry teachers' content knowledge and pedagogical content knowledge interact while teaching electrochemistry?

1.3 Definitions of important terms

Pedagogical content knowledge (PCK) was defined as Shulman (1986) as "the ways of representing and formulating the subject that make it comprehensible to others" (p. 9). Shulman (1987) also added that PCK represents "the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (p.8) PCK gives a chance to discriminate the chemist from chemistry teacher. Shulman (1987) mentioned that "…distinguishing the knowledge base of teaching lies at the intersection of content and pedagogy, in the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students" (p.15) In this study, pedagogical content knowledge of pre-service chemistry teachers was studied.

Content knowledge (CK) was defined by several researchers (Tamir, 1988; Shulman, 1986; Jüttner et al., 2013; McConnell et al., 2013) in different perspectives. CK, often called subject matter knowledge, is considered as crucial precondition for effective teaching (Shulman, 1986; Jütnerr et al., 2013). According to Jüttner et al. (2013) content knowledge includes declarative knowledge meaning "knowing that", procedural knowledge meaning "knowing how" and conditional knowledge meaning "knowing how and why". In this study, content knowledge refers to knowledge about fundamental concepts, facts and principles of subject, knowledge regarding connection of chemistry with other disciplines and/or real life applications of chemistry and knowledge regarding chemistry concepts and principles.

Orientation to science teaching, accepted as overarching component of PCK, refers to teachers' knowledge and beliefs about purposes and goals for science teaching (Magnusson et al. 1999). For this study, the science teaching orientation approach of Friedrichsen and Dana (2005) was preferred. Friedrichsen and Dana (2005) mentioned that science teaching orientation has a complex nature, and each teacher may have more than one purposes and goals for teaching hence they examined the science teaching orientation under two components namely: central and peripheral goals.

Knowledge of learner (KoL) is one of PCK components that is pertained to knowledge that teachers are supposed to know about students. This component is composed of prerequisite knowledge for learning the specific science topic, and knowledge on difficulties and misconceptions that students may have related to the science topic (Magnusson et al. 1999)

Knowledge of instructional strategy (KoIS) is one of PCK components that consisted of subject specific and topic specific strategies. While subject specific strategies are appropriate and implementable to science subjects (e.g. Learning cycle, guided inquiry), topic-specific strategies include representation and activities to teach a specific topic (e.g. animations, demonstration). (Magunusson et al., 1999)

Knowledge of science Curriculum (KoC) is another component of PCK including the knowledge of goals and objectives, and knowledge of materials and programs

(Magunusson et al., 1999) as well as knowledge of both vertical and horizontal relation of curriculum for a subject (Grossman, 1990)

Knowledge of assessment (KoAs) is another component of PCK, comprised of the knowledge of dimension of science learning important to assess, and knowledge of the methods using while assessing that learning (Magnusson et al. 1999; Park & Oliver, 2008)

CHAPTER 2

LITERATURE REVIEW

This chapter included the review of the PCK literature. The historical development of PCK and PCK models, research on pre-service teachers' PCK and research on PCK and CK relation presented respectively.

2.1 Historical Development of PCK and PCK Models

First, Shulman (1986) described the pedagogical content knowledge (PCK) concept as "which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching" (p. 9). According to Shulman's conception, PCK includes two key components respectively knowledge of representations of subject with analogies, demonstrations, examples and explanations, and knowledge of students' learning difficulties and preconceptions regarding specific topics (Hashweh, 2005).

In the later article Shulman (1987) described ''the knowledge base for teaching'' as the knowledge that teacher should possess and it includes PCK. This knowledge base includes seven categories namely content knowledge, PCK, curriculum knowledge, learners and their characteristics, educational contexts, and educational purposes. In this second article, Shulman described PCK as a category on its own not as a subcategory as described in the article in 1986.

Other scholars have also adopted two key components of PCK as I mentioned above, while they were elaborating the Shulman's model. Furthermore, the researchers have extended the PCK concept by adding the categories of knowledge which were mentioned in Shulman's knowledge base for teaching. One of these researchers is Tamir (1988) who mentioned that PCK is composed of four components namely knowledge of students' common conceptions and misconceptions, knowledge of curriculum, knowledge of instructional strategies and knowledge of assessment. Also, Grossman (1990) described PCK including knowledge of strategies and knowledge of students' conception and understanding similar with Shulman's PCK concept. Furthermore, Grossman added two other components to PCK concept namely knowledge and purposes about the particular topic and knowledge of curriculum materials. In Grossman model, teachers' PCK is the center of the three main domains; subject matter knowledge, pedagogical knowledge and context knowledge. Furthermore, in Grosmass's model subject matter knowledge was interpreted as a separate category from pedagogical content knowledge (Canbazoglu et al., 2010). Also, Mark (1990, as cited in van Driel et al., 1998) extended Shulman's model by adding the subject matter and media component to PCK. In addition, Mark emphasized that it is not possible to separate PCK from both subject matter knowledge and pedagogical knowledge completely. The other scholars Fernandez-Balboa and Stiehl (1995) identified PCK with five components respectively subject matter, the students, instructional strategies, the teaching context and teachers' teaching purposes. Some other scholars also extended the Shulman's model by adding some of the categories of knowledge over time (e.g. Hasweh, 2005 and Loughran, Berry, & Mulhall, 2012). Table 1 summarizes the conceptualizations of PCK of various authors.

Magnusson, Krajcik and Borko (1999) described pedagogical content knowledge as transformation process ''of several types of knowledge for teaching'' (p. 95). According to Magnusson et al. (1999) PCK was composed of five components: (a) orientation toward science teaching, (b) knowledge of science curriculum, (c) knowledge of science assessment, (d) knowledge of students' understanding, and (e) knowledge of instructional strategies. Magnusson et al. (1999) presented a model to represent the relationship among the domains of teacher knowledge and these domains were subject matter knowledge, pedagogical knowledge, knowledge and belief about context, and pedagogical content knowledge as shown in

Figure 1 According to their model, PCK is influenced by three domains namely knowledge and belief about context, subject matter knowledge and pedagogical knowledge.

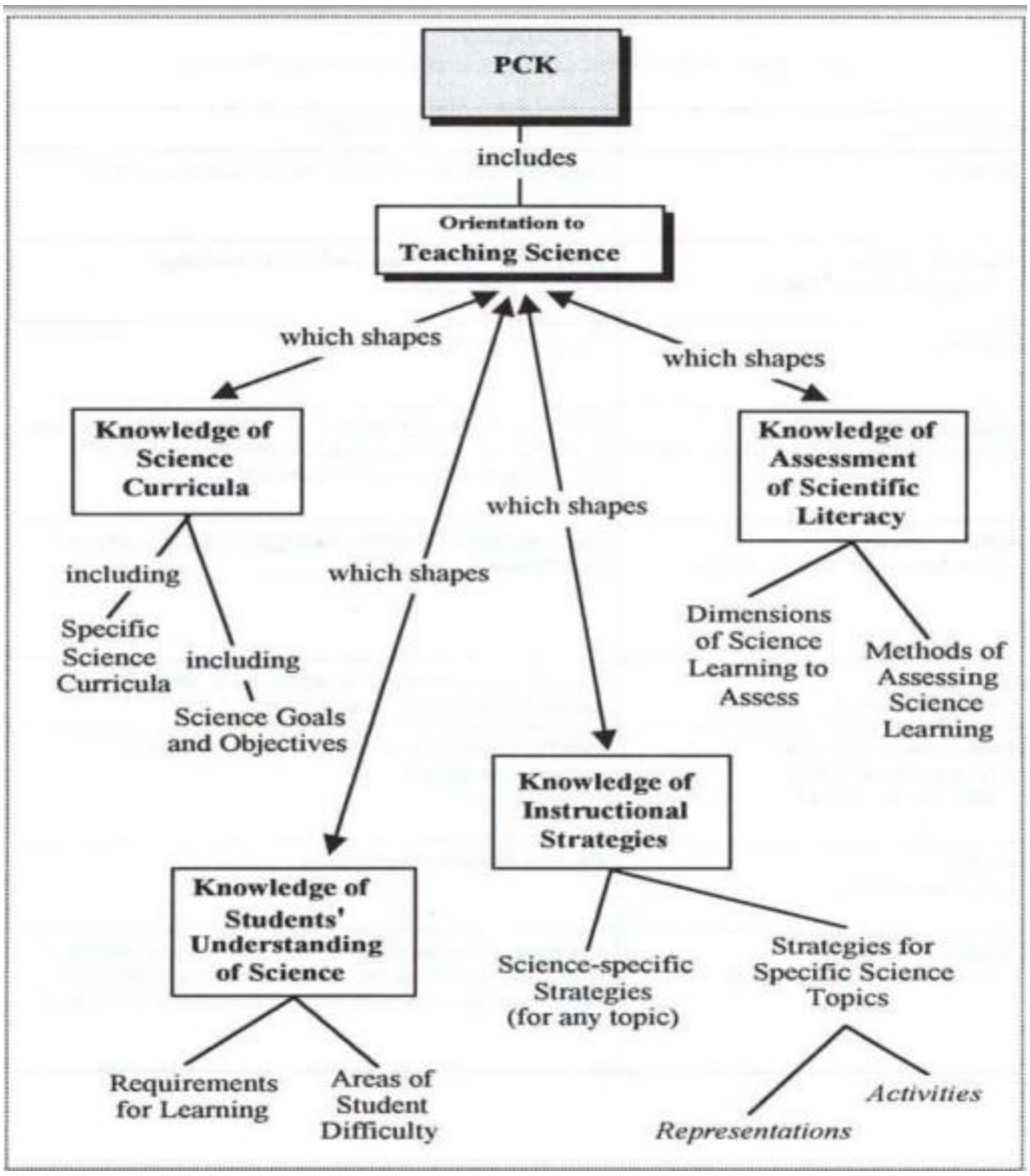


Figure 1. Model of PCK showing the components of PCK for science teaching (Magnusson et al., 1999, p.99)

In the light of these studies it can be concluded that there is no consensus about the concepts of PCK. Yet, it can be seen from the Table 1, van Driel, de Jong and Verloop (2002) emphasized all scholars agree on Shulman's two key component which are knowledge of representations and instructional strategies of subject matter, and understanding of learner conceptions and learning difficulties regarding a specific content area. According to De Jong, van Driel and Verloop (2005) these two components should be used together: the better teachers become aware of students' learning difficulties with a specific topic, and the more activities they have at this topic, the more effective they can teach in this topic.

Table 1. Different conceptualization of pedagogical content knowledge*

Knowledge of :									
Scholars	Subject matter	Representation and strategies	Students learning and conceptions	General pedagogy	Media	Context	Purposes	Curriculum	Assessment
Shulman (1987)	a	PCK	PCK	a	b	a	a	a	b
Tamir (1988)	a	PCK	PCK	a	b	b	b	PCK	PCK
Grossman(1990)	a	PCK	PCK	a	b	a	PCK	PCK	b
Marks (1990)	PCK	PCK	PCK	b	PCK	b	b	b	b
Fernandez et al.(1995)	PCK	PCK	PCK	b	b	PCK	PCK	b	b
Hasweh(2005)	PCK	PCK	PCK	PCK	b	PCK	PCK	PCK	PCK
Loughran et al. (2006)	PCK	PCK	PCK	PCK	b	PCK	PCK	b	b
Magnusson et al. 1999	a	PCK	PCK	a	b	a	PCK	PCK	PCK

Note. [a] Distinct category in the knowledge base for teaching; [b] Not discussed explicitly.
*Developed from Canbazoglu et al. (2010); Park & Oliver (2008) and Van Driel et al. (1998).

Furthermore, there is also agreement on that PCK concerns teaching of specific topics so PCK is a construct different from related subject matter knowledge (De Jong & van Driel, 2004; van Driel et al., 2002). However, some scholars like Mark (1990, as cited in De Jong & van Driel, 2004) emphasized that pedagogical content knowledge always cannot be distinguished from subject matter knowledge completely. Although there is a consensus that PCK concerns teaching of particular topics, there have been few studies on topic specific PCK in science education (Mulhall, Berry, & Loughran, 2003). Abell (2008) and van Driel et al. (1998) pointed out that whereas there has been many studies conducted related with PCK, few studies focused on PCK with respect to a specific topic such particulate nature of matter (Boz & Boz, 2008; Canbazoglu, et al., 2010), chemical equilibrium (van Driel et al., 1998), macroscopic and microscopic properties of matter (van Driel et al., 2002), gas laws (Sande, 2010) and methods of separation of mixtures (Aydın, Boz & Boz, 2010). Veal and Makinster (1999) emphasized that there is an increasing need for improving topic- specific PCK as an instructional model for pre-service science teachers.

PCK is a special form of knowledge for teaching (van Driel et al., 1998) which includes knowledge about students' learning difficulties and conceptions regarding the specific topic, knowledge of appropriate instructional strategy and techniques to remedy students' difficulties, and the ability for transforming subject matter knowledge to a more understandable content for students; in other words, PCK is teachers' practical knowledge for teaching effectively in their instruction (Magnusson et al., 1999). It can be concluded that pre-service or beginning teachers generally have little or no PCK (de Jong, Veal & van Driel, 2002) and in order to develop their PCK they should experience instructional strategies regarding teaching particular topics in practice (de Jong et al., 2005). But, the studies focused on development of pre-service and beginning teachers' PCK and how this development can be facilitated have been very few (de Jong et al., 2005). Understanding the process of PCK development of pre-service teachers is essential to improve teacher education programs (de Jong et al., 2005).

2.2 Research on pre-service teachers' pedagogical content knowledge

In the literature, there have been many studies investigating pre-service science teachers' PCK (Aydin et al., 2013; De Jong & Van Driel, 2004; Halim & Meerah, 2002; Hume & Berry, 2011, 2013; Kaya, 2009; Loughran et al., 2008; Nilsson, 2008; Van driel et al., 2002). Most of these studies focused on development of pre-service teachers' PCK and argued various suggestions to promote the development of pre-service teachers' PCK.

Magnusson et al. (1999) stated that the development of teachers' PCK is a complex process which encompasses the nature of the topic, the context in which the topic is taught, and the way a teacher reflects on teaching experiences. These authors concluded that a pre-service teacher could not completely develop all the components of PCK with the teacher education program. Grossman (1990) identified four major sources of PCK development: (a) disciplinary education, which may lead to improvement in subject matter knowledge and knowledge of teaching strategies (e.g., demonstrations and analogies) for teaching, (b) observation of classes both as a student and as a pre-service teacher may lead to enhancement in knowledge of students' conceptions and learning difficulties, (c) classroom teaching experiences may, promote pre-service teachers' knowledge of teaching activities associated with specific topic, and (d) specific courses or workshops during teacher education may also influence teachers' PCK.

The impact of these four factors is not clear due to the lack of studies on the development of PCK (de Jong et al., 2005). In the light of a few studies, classroom teaching experience contributes the improvement of PCK (van Driel et al., 2002) and the impact of workshop on enhancement of PCK was studied by Clermont, Krajcik and Borko (1993). Furthermore, the role of subject matter knowledge on development of teachers' PCK was also investigated (van Driel et al., 1998; 2002; Mavhunga, 2014)

For instance, Clermont et al. (1993) studied prospective chemistry teachers' PCK in a specific domain as chemical demonstration as an instructional strategy. They investigated the effects of workshops on improvement of pre-service teachers' PCK and claimed that specific workshops lead to significant development on pre-service teachers' PCK. On the other hand, van Driel et al. (2002) found that workshop sessions had a minor effect on development of pre-service teachers' PCK in terms of knowledge of teaching strategies. Van Driel, Verloop and de Vos (1998) also investigated the impact of participation of workshop on improvement of PCK with respect to chemical equilibrium, but their sample was composed of experienced chemistry teachers. The findings were consistent with the previous study as participation in workshop had serious impact on most of the teachers' PCK in terms of gaining knowledge about specific learning difficulties and misconceptions. In this research, van Driel et al. (1998) emphasized that subject matter knowledge and teaching experiences are basic components to develop teachers' PCK. Also, Smith and Neale (1989) mentioned that adequate subject matter knowledge is prerequisite for development of teachers' PCK.

Geddis (1993) studied on the transformation process of pre-service teachers from subject matter knowledge into content knowledge which is teachable. Based on the result of the study, he concluded that pre-service teachers can improve their PCK with respect to instructional strategies by studying students' preconceptions related with specific topic during teacher education programs and by comparing and interpreting students' preconceptions with their own conceptions. Similar with Drechsler and van Driel (2008), Geddis (1993) mentioned that having the knowledge of learners' conceptions and preconceptions may contribute the development of topic specific PCK of pre-service teachers.

The study about the other contributing element of PCK, the teaching experiences, was discussed in van Driel, de Jong and Verloop's study. Van Driel, De Jong, and Verloop (2002) conducted a study to describe pre service teachers' pedagogical content knowledge (PCK) and investigated its development in the domain of macro-micro. The sample of the study was composed of 12 pre-service chemistry teachers from two universities (Utrecht University and Leiden University) who had little or no teaching experiences. The multi method approach was used to observe the improvement of PCK. The data were collected via questionnaire, interviews with each pre-service teacher and their mentors, and workshop sessions in teacher education program over one semester. The result of the study indicated that three factors namely classroom experiences, university-based workshop and meetings with mentors are contributors to improve pre-service teachers' PCK. Furthermore, most of the pre-service chemistry teachers in this study showed a significant improvement of PCK in the domain of macro-micro. According to pre-service teacher and their mentors, the teaching experiences have the strongest impact on their growth of PCK. Pre-service teachers' teaching experiences improved teachers' knowledge of teaching strategies and demonstrations, and knowledge of students' difficulties and misconceptions about the specific topic. This finding is similar with other studies in this area (Lederman et al., 1994; Hashweh, 2005). In Hashweh's study (1985, as cited in Hasweh,2005), while experienced teacher did not spend so much time for planning, only they skimmed over their previous knowledge about the teaching topic, the inexperienced teacher endeavored to make planning and form analogies, examples, activities or demonstrations to use in teaching.

Beside this, the university based workshops have also minor effect on improvement of pre-service teachers' PCK in van Driel et al. (2002) study in terms of knowledge of specific teaching strategies and knowledge of students' learning difficulties. At the same time, workshops and articles which are discussed during the workshops help some pre-service develop their subject matter knowledge.

The another research with pre-service chemistry teacher was conducted again by de Jong et al. (2005) in the experimental course module which stressed mainly learning from teaching by relating teaching experiences with workshops. It means that pre-service teachers learn in an active way with participating in real teaching practices, in this way learning become more meaningful for them. The purpose of the study was to promote pre-service teachers' PCK of using particular models. Data were collected via answers to written assignments, transcripts of workshop discussions, and reflective lesson reports, written by the participants. The findings revealed that all pre-service teachers became aware of the importance of using models of molecules and atoms, and gain deeper understanding of students' difficulties with using of particle models. Pre-service teachers developed their PCK of using particular models through learning from teaching, even though this development was different for different pre-service teacher.

De Jong and van Driel (2004) conducted their research with the similar perspective with the previous study. They also investigated the development of pre-service chemistry teachers' PCK of the multiple meanings of chemistry topics (macroscopic, microscopic and symbolic) in a naturalistic case study which focused on learning from teaching instead of learning of teaching. Each pre-service teacher was asked to choose a chemistry topic and teach respect macroscopic, microscopic and symbolic dimensions of chemistry. The pre-service teachers were interviewed with semi structured interviews before and after the lessons. The teaching experiences lead to improvement on pre-service teachers' knowledge of teaching difficulties and strategies, and also they gain a better awareness about students' difficulties in understanding three dimension of chemistry and transforming between these dimensions.

Within the literature investigating pre-service teachers PCK, researchers used varied tools to measure pre-service teachers PCK. Several studies used Content Representations (CoRes) and Pedagogical and Professional-Experience Repertoires (PaP-eRs) to capture and portray pre-service teachers' PCK (Adadan & Oner, 2014; Aydin et al. 2013; Hume & Berry, 2011; 2013; Loughran et al., 2008; Nilsson & Loughran, 2012). Aydin et al. (2013) investigated the development of three pre-service chemistry teachers' PCK on rate of reaction topic during the CoRe based mentoring enriched practicum course. During this course, pre-service teachers were provided explicit PCK introduction, CoRe as a lesson planning format, microteaching, and educative mentoring by teaching assistants. The main purpose of the study was to investigate the effectiveness of practicum course on pre-service teachers' professional development as a teacher regarding the rate of reaction topic. In this study, CoRe was used both as a lesson plan and to portray pre-service teachers' PCK with the help of stimulated recall interviews.

2.3 Research on PCK and CK relation

There have been studies exploring the impact of content knowledge with novice and expert teacher perspective in the same subject domain. For instance, Geddis, Onslow, Beynon and Oesch (1993) studied with two pre-service chemistry teacher and an experienced teachers to examine their PCK on isotopes topic. Researchers defined PCK as "knowledge that play a role in transforming subject matter into forms that are more accessible to students" (p. 582). In this study, PCK was including knowledge of students' prior knowledge, knowledge of instructional strategies, curricular saliency and alternative representations for teaching. According to findings of the study, pre-service teachers focused on transmitting the knowledge so they ignored students' prior knowledge. On the other hand, cooperating teacher enacted an instructional strategy taking into account students' prior knowledge on the topic. Researches attributed this difference between pre-service teachers and cooperating teacher to having good sense of curricular saliency. Researchers mentioned that curricular saliency had a crucial role on "assisting teachers to deal with the tension between covering the curriculum and teaching for understanding" (p.589).

In another study, Käpylä et al. (2009) investigated the influence of the quality of content knowledge on PCK on the topic of photosynthesis and plant growth. The participants of the study were 10 primary and 10 secondary pre-service science teachers. While their PCK was measured utilizing lesson preparation method (Van der Valk & Broekman, 1999), questionnaire was conducted to investigate participants' CK. Lastly interview took place in order to get detailed information both pre-service teachers' PCK and CK. In terms of CK, both group of pre-service teachers had misconceptions and inaccuracies however, secondary biology pre-service teachers (content experts) have less misconceptions than primary pre-service teachers (content novices). Excluding knowledge of assessment, all PCK components were investigated during the study. Content experts were more aware of the learners' possible misconceptions compared to their counterparts. Regarding knowledge of curriculum, biology pre-service teachers usually emphasized the most important lesson content than primary student teachers. On the other hand, the level of content knowledge had no significant effect on pre-service teachers' knowledge on instructional strategies. Käpylä et al. (2009) classified science teaching orientation into two groups namely: constructivist and conceptual teaching orientations. While content novices were mostly constructivist, content experts were in transitional stage between these two orientations. The study presented valuable findings but could not provide empirical evidence how CK effect participants' teaching in the real classroom due to research method used in the study.

Rollnick, Bennett, Rhemtula, Dharsey and Ndlovu (2008) avoided the limitation of Käpylä et al. (2009) by conducting classroom observations during the study to examine the role of SMK on PCK of two in-service South Africa teachers while teaching the mole and chemical equilibrium topics. Data were collected using questionnaire, observation, interviews and content representations (CoRe) and pedagogical and Professional-experience repertories (PaP-eRs) proposed by Loughran, Berry and Mulhall (2004). Rollnick and her colleagues mentioned that PCK is an amalgam of knowledge of subject matter, knowledge of students, context and general pedagogy and when these domains combined "produce directly observable products in the classroom, which we refer to as 'manifestations" (p. 1380). These manifestations refers subject matter representation, topic specific instructional strategies, curricular saliency and assessment. The findings of the study indicated that lack of SMK on the topics constrained their teaching and limited their flexibility in their teaching. However, having powerful PCK lead teachers to handle the explaining the SMK with combining knowledge of students, context and pedagogical knowledge. Moreover, researchers concluded that even if teachers have similar SMK, their PCK will be qualitatively different due to different context.

There have been studies investigating the effect of content knowledge on teachers PCK within and outside of their specialism. Several studies investigated the relation between teachers' SMK and PCK in and out their subject specialism. In an older study, Hashweh (1987) examined the effect of subject matter knowledge on teaching within and outside of their specialism. The researcher studied with 6 experienced secondary school teacher, three physics and three biology teachers. He evaluated their subject matter knowledge in both physics (levers) and biology (photosynthesis) topics using subject matter knowledge tasks including free recalls, concept maps line labeling, and sorting. In terms of assessment of teachers' teaching, questions were asked related to assessment, instructional strategy, students' prior knowledge and student difficulties to assess teachers' planning and interactive teaching process on both of the physics and biology topics. Hashweh (1987) listed the properties of teachers' content knowledge within their specialism as: "…teaches tended to have a) more detailed topic knowledge b)more knowledge of other discipline concepts, c) more knowledge of higher-order principles that are basic to their discipline and d) more knowledge of ways of connecting the topic to the other entities in the discipline" (p. 113) Findings of this study shed light on the effect the subject matter knowledge on teachers' planning and teaching. Regarding knowledge organization, unknowledgeable teachers tended to follow the textbook content structure quite closely, and sometimes failed to detect the main theme due to lack of prior subject matter knowledge. However, knowledgeable teachers offered alternative organization for the content and they used the chapter structure only if it overlapped with their prior subject matter knowledge and approach. In terms of assessment of learners' understanding, unknowledgeable and knowledgeable teachers were differentiated based on their subject matter knowledge. While unknowledgeable teachers tended to ask low cognitive level questions as recalling the topic presented in the textbook, knowledgeable teachers tended to ask cognitively higher level questions required students' interpretation using the knowledge presented in the textbook. Moreover, unknowledgeable teachers were unable to detect learners' preconceptions and sometimes they might reinforce their misconceptions by criticizing students' explanations wrongly. On the other hand, knowledgeable teachers were more likely recognize learners' preconceptions and correspond correctly students' comments on the topic. However, in some cases knowledgeable teachers behave like novice outside their expert field and they had difficulty in coping with students' difficulties and misconceptions.

Similarly, Ingber (2009) examined six science teachers' PCK while planning within and outside of their area of expertise. Researcher examined teachers' PCK in terms of teachers' planning, use of sources, use of instructional strategy and the science content planned to use. Data was collected via survey and think aloud sessions. Findings of the study indicated that teachers used appropriate terminology regarding content they planned to teach and associated concepts more in their area of expertise compared to out of their area. Moreover, teachers were more aware of the sources they used to improve their content knowledge and teaching while preparing to teach within their expert area than teaching out of the expert area. Ingber (2009) interestingly found that teachers' choice for instructional strategies in their planning was independent from their expert areas. This result was parallel with Käpylä et al. 2009. Finally, researcher stated that teachers may know about the content and how to present that content more than presented in their planning due to the context in which they teach a particular topic.

Similar to other studies, Sanders et al. (1993) examined secondary science teachers' planning, teaching and reflecting while teaching in and out of their expert field. In addition to this, researcher aimed to investigate the effect of teachers' content knowledge, pedagogical knowledge and pedagogical content knowledge on their planning, teaching and reflection process. Data obtained from observations of teachers' teaching in both science field and interviews after their teaching experiences. Results indicated that while teachers planning and reflection were similar for in and out of their expert area, their teaching were differentiated based on their expert area. Researchers mentioned that experienced teachers acted like novice teachers while teaching a new subject that was unfamiliar for them. In terms of planning, in their expert area, teachers had lots of instructional materials as handouts and activities and they can easily plan flow of their lesson. However, out of their expert area, they had difficulty in finding sources and need help from outside so they complained about spending so much time for planning. Furthermore, SMK influenced their planning in terms of determining the key concepts that was important for students to learn and how to present the content. Also pedagogical knowledge had crucial role on planning. For instance, while teaching outside their specialty, they had difficulty in time management and they could not forecast how long the activities would last. Regarding pedagogical content knowledge, teachers they had difficulty in selecting appropriate instructional strategy and predicting possible problem that learners may have while teaching out of their area of certification. During teaching, differences were also detected for three teachers. While teaching the subject that were not familiar, in other words, they have limited content knowledge on the topic, teachers were sometimes unable to address students' questions and struggled to provide explanations to them that was similar to findings of Hashweh (1987). They dominated discussion and gave less chance to students for talking, and used teacher centered activities. Furthermore, they reluctant to move beyond their lesson plan. On the other hand, within their specialism, teachers tended to talk less and prepare student centered activities. Also when they came across questions, they connected the idea to lead students understand deeply. In addition, they handle the changes occurred during the lesson and direct the flow of the activities smoothly due to being familiar to the subject.

In addition to studies conducted with in-service teachers, there have been studies investigating the role of content knowledge on PCK at pre-service teacher level. For example, Halim and Meerah (2002) studied with 12 Malaysian pre-service physics teachers and investigated pre-service teachers' PCK in terms of knowledge of instructional strategy and knowledge of students' understanding components. Researchers found a relationship between two components of PCK and content knowledge. They reported that most of the pre-service teachers' content knowledge on physic concepts were deficient and they had misconceptions related to physic concepts similar to students so they were unable to identify students' misconceptions. Researcher concluded that being unaware of students' misconceptions were associated with teachers' lack of content knowledge as found in Hashweh (1987). Regarding knowledge of instructional strategy, pre-service explained physics concepts by paraphrasing their own understanding, their presentation of SMK in an appropriate and understandable way for students "were impeded by their own poor content knowledge" (p.223)

Similar findings were presented by Van Driel et al. (2002) study, they investigated how pre-service chemistry teachers' teach chemistry topics taking into account macroscopic and microscopic representations. Results indicated that although teaching experience had the most crucial role on development of pre-service teachers' PCK development, the role of SMK on PCK development could not be underestimated. In addition, following university based workshops sessions and meeting with mentor were also attributed the development of PCK and SMK in a certain extent.

Besides the studies focused on the interaction between PCK and CK in qualitatively, there have been studies investigated this interaction with quantitatively. Jüttner et al. (2013) developed a paper-pencil test to measure PCK and CK of biology teachers. In this study, Jüttner and her colleagues accepted CK and PCK were correlated but they were separate knowledge domains. Researcher categorized content knowledge into three dimension namely declarative knowledge (knowing that), procedural knowledge (knowing how) and conditional knowledge (knowing how and why). Regarding PCK, they focused two component of PCK: knowledge of students' understanding and knowledge of instructional strategy. After the development process of CK and PCK test on neurobiology, vertebrates and plants, they conducted the tests to 158 biology teachers. Results indicated that there have been low but significant correlation between teachers' CK and PCK. In other words, PCK and CK were interacted each other but these knowledge domains were different.

In another quantitative study, Tepner and Dollny (2014) used similar methodology and content knowledge categorization with Jüttner et al. (2013) but in chemistry subject domain. They conducted paper-pencil test to measure chemistry teachers' CK and PCK at working non-intensified and intensified level. The questionnaire including question related to main chemistry topics namely: structure of atoms and the periodic table, chemical bonding, and chemical reactions using acids and bases. The results showed that it was found a significant correlation ($r = 0.36$, $p < 0.001$) between CK and PCK. In other words, if teachers have good CK, this lead them to develop sophisticated PCK. Moreover, according to results, teachers' CK level differentiated based on the school level. It was found a higher correlation between CK and PCK at non-intensified level so it could be concluded that while possessing basic level of CK was precondition for developing PCK, having robust CK did not affect having sophisticated PCK to the same degree.

There have been few studies pertained to content knowledge or subject matter knowledge, and pedagogical content knowledge in pre-service teacher education level within the science education domain in Turkey. (Ozden, 2008; Canbazoglu et al., 2010; Usak, Ozden & Eilks, 2011; Kaya, 2009)

Canbazoglu et al., (2010) examined the relationship between pre-service science teachers' SMK and PCK on particular nature of matter (PNM) topic. The participants of the study were pre-service science teachers and the study was qualitative in nature. Data were collected via observation, interview and document analysis methods. SMK of the participants were measured utilizing SMK test including questions related to PNM and 5 preservice teachers out of 40 were selected for the study concerning their SMK level. The results of the study showed that pre-service teachers have limited SMK and had misconceptions regarding PNM topic. For instance, pre-service teachers had difficulty in associating molecule concept with atom, element and compound and during the instruction they avoid to responds students questions related to them. Related to the movement of particles in solids, liquids and gases, pre-service teachers had inadequate knowledge related to it. Researchers emphasized that although there have been an objective in the curriculum related to movement of particles, the pre-service teachers ignored this objective both preparing their lesson plan and enacting their instruction. Researchers concluded that limited SMK hinder to teach effectively. In terms of knowledge of instructional strategy, pre-service teacher generally used traditional teaching methods, questioning, models and daily life applications of the topic. Pre-service teachers mentioned that although they have heard about demonstrations, drama, concept map, brain storming but they did not have adequate knowledge regarding advantages and disadvantages, and application of these instructional strategies. In addition, pre-service teachers were not aware leaners' possible misconceptions. Researchers mentioned that pre-service teachers' limited SMK and having misconception associated with their inability to recognize the learners' misconceptions. Furthermore, pre-service teachers did not have adequate knowledge pertained to alternative assessment techniques and they preferred to use traditional assessment strategies. Finally, regarding knowledge of curriculum, most of the pre-service teachers aware of the sequence of the topic, and which topic present before and after the PNM topic in the curriculum. To sum up, researchers mentioned that SMK and PCK were related and inadequate SMK limit pre-service teachers in terms of planning and enacting instruction.

Ozden (2008) conducted the study with the 28 pre-service elementary science teachers to investigate the relationship between content knowledge and pedagogical content knowledge on phases of matter topic. Data collection tools were lesson plans, content knowledge test and semi-structured interviews. This study was used Magnuson et al. PCK model but focused just three components namely knowledge of students' understanding, knowledge of curriculum and orientation in science teaching. Results indicated that pre-service teacher did not have robust content knowledge on phases of matter topic. Although most of the pre-service teachers had adequate knowledge related to general properties of phases of matter, they had difficulty in heat and temperature, changes of matter and vapor pressure concepts. The findings related to PCK components indicated that, pre-service teachers were aware of at least one of the learners' possible misconceptions and difficulties on phases of matter. In addition, pre-service teachers mentioned that the possible source of this misconceptions may be the abstract nature of the topic. Regarding knowledge of curriculum component of PCK, researcher just focused on the main teaching goals of the participants. In terms of knowledge of instructional strategy, participants were preferred to use experiments, drama, group working and games for teaching. Participants' orientation to science teaching was also examined and found that most of the participants had constructivist teaching approach based on the data collected from interviews and lesson plans. Furthermore, in the light of the data analysis, researcher listed the difficulties that participant experience while preparing the lesson plan as: lack of content knowledge, classroom management, motivation and inadequate knowledge of students' understanding of science. Then, researcher identified the educational needs of pre-service teachers. Most of the participants emphasized that they need support in terms of content knowledge, knowledge of instructional strategies, knowledge of students' understanding of science and knowledge of curriculum. Although the study did not compare participants' PCK in terms of the different level of CK, the conclusion of the study was content knowledge had a crucial role on development of PCK in other words, content knowledge was essential for effective teaching.

Similar to other studies, Usak, Ozden and Eilks (2011) conduct a qualitative study with 30 science student teachers in chemistry education to investigate the participants' subject matter knowledge and pedagogical content knowledge concerning chemical reactions. Data were collected via multiple choice test including open-ended explanations and semi-structured interviews. Similar to Ozden (2008), researchers focused on three components regarding PCK as knowledge of students' learning difficulties, knowledge of instructional strategies and knowledge of assessment. Findings of the study showed that student teachers did not have adequate level of conceptual understanding of main concepts of chemical reactions such as chemical reaction equations, stoichiometry or limiting agent. Regarding PCK, researchers get eight student teachers' view on how to teach chemical reactions utilizing interviews. Concerning knowledge of learner component, student teachers were not aware of the possible learning difficulties and misconceptions that students may have on chemical reactions. Regarding to instructional strategy half of the participants planned to use lecturing. In terms of assessment, student teachers did not have knowledge on assessment related to chemical reactions, thy just familiar to traditional methods as multiple choice etc. Furthermore, researcher investigated the beliefs of pre-service teachers to science teaching and it was found that pre-service teachers had very traditional and teacher-centered beliefs towards chemistry teaching. Usak et al. (2011) mentioned that these beliefs and lack of robust subject matter knowledge would prevent the formation of PCK.

Different from studies conducted in qualitative in nature, Kaya (2009) studied with 216 pre-service science teachers to investigate the relation between SMK and PCK and the interaction among PCK components on ozone layer depletion topic with a quantitative study. A survey comprised of open-ended questions was used to identify participants' SMK on the topic and formed three groups of 25 pre-service teachers, taking into account the knowledge level as naïve, plausible and appropriate. Then, interviews were conducted to examine participants' PCK, excluding science teaching orientation component. The researcher found that most of the pre-service science teachers did not have enough subject matter knowledge on ozone layer depletion topic. Regarding the relationship between SMK and PCK, it was found that there was a strong relationship between them ($r = 0.77$, $p < .001$). Moreover, there were significant positive correlations between pre-service teachers' SMK and various PCK components, however, knowledge of assessment was not associated with the other three PCK components. Kaya (2009) compared and contrasted participants' PCK for different SMK levels and concluded that "for the PSTs with strong subject matter knowledge, there was more appropriate pedagogical knowledge, whereas there was more naïve pedagogical knowledge for those with low subject matter knowledge." (p. 979).

To sum up, the studies conducted to examine the relation between content knowledge and pedagogical content knowledge focused on some of the PCK components rather than examining PCK as a whole. Moreover, they generally used qualitative research methods. In addition, the common limitation for these studies were lack of observation of practical knowledge of pre-service teachers could not be investigated except Canbazoglu et al.'s (2010) study in Turkey.

CHAPTER 3

METHODOLOGY

The relation between CK and PCK has been often debated in the literature (Kind, 2009) but there is no consensus to date about how they are related. The purpose of this study is to examine pre-service chemistry teachers' PCK on electrochemistry, and how CK and PCK interact while teaching electrochemistry. This chapter will provide the research design of the study. Then the instruments used for data collection and data analysis were explained. I also explained the trustworthiness issue, ethical considerations, limitations and assumptions of the study.

3.1 Research questions

The main research questions of this study are:

How do pre-service chemistry teachers' content knowledge and pedagogical content knowledge interact including STO, KoL, KoIS, KoAs and KoC while teaching electrochemistry?

The sub-research questions of this study were:

1. What is pre-service chemistry teachers' content knowledge regarding electrochemistry?

2. What is the nature of pre-service chemistry teachers' PCK regarding electrochemistry?

   a) What is nature of pre-service chemistry teachers' science teaching orientation regarding electrochemistry?

b) What is nature of pre-service chemistry teachers' knowledge of learner regarding electrochemistry?
c) What is nature of pre-service chemistry teachers' knowledge of instructional strategy regarding electrochemistry?
d) What is nature of pre-service chemistry teachers' knowledge of curriculum regarding electrochemistry?
e) What is nature of pre-service chemistry teachers' knowledge of assessment regarding electrochemistry?

3. How do pre-service chemistry teachers' content knowledge and pedagogical content knowledge interact while teaching electrochemistry?

3.2 General Research Design

Qualitative research both focuses on product and process of the study (Fraenkel & Wallen, 2006). The most important point in doing qualitative research is to move beyond the known and to understand perspective of the participants hence this leads to improve development of empirical knowledge (Corbin & Strauss, 2008) In this study, qualitative research was conducted to gain a more holistic understanding regarding the complex nature of pre-service teachers' PCK and how their PCK interacts CK while teaching electrochemistry.

According to qualitative research, action occurred can best be interpreted and comprehended when it is observed in the natural setting (Bogdan & Biklen, 1998; Marshall & Rossman, 2006). During this study, data were collected in the real classroom environments via multiple sources as CoRe, interviews and video recordings.

Based on the purpose of the study and research questions, qualitative research design was appropriate for the current study. In the related literature, there have been studies parallel with this study also preferred qualitative research design (e.g. Childs & McNicholl, 2007; Davis & Petish, 2005; Käpylä et al., 2009; Mthethwa-Kunene, Onwu & de Villiers, 2015; Rollnick & Mavhunga, 2014).

Merriam (1998) defined the qualitative research as “an umbrella concept covering several forms of inquiry that help us to understand and explain the meaning of social phenomena with as little disruption of the natural setting as possible” (p.5). Qualitative research included five different approaches namely narrative, phenomenological, grounded theory, ethnographic and case study (Creswell, 2007). Yin (2008) defined case study as research process “A case study is 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.18).

A case study provides researchers to gain a full understanding about the phenomenon (Merriam, 1998) and Merriam (1998) underlined the reason of choosing case study as “..the importance of a process rather than an outcome as justification for selecting a case study” (p. 33). Case study guided this study in terms of studying an issue (pedagogical content knowledge and content knowledge interactions) examined through more cases (pre-service teacher with low and high content knowledge) over time, through detailed data collection via multiple sources (observation, CoRe, interviews, documents, and content knowledge questionnaire) within the bounded system (practice teaching course) (Creswell, 2007).

There are different types of case study which are distinguished in terms of the size of the bounded case and intent of the case analysis (Creswell, 2007). Regarding the size of the case study, the case may involve one individual, several individuals or a group. In terms of the intent of the case analysis, there are three types; namely single instrumental case study, multiple case study and intrinsic case study. In this study, two pre-service teachers enrolling in science teaching experience course, during one semester in teacher education program comprised the case. The purpose of the study is to examine the interaction of pre-service teachers’ content knowledge and pedagogical content knowledge which one has high content knowledge and the other one is low content knowledge so two pre-service teachers can be described as multiple case study.

3.3 Sampling and participant selection

Due to the nature of qualitative study and purpose of this study, I preferred to study with few pre-service teachers to get intense information regarding each case. Purposeful sampling was used to select the participants. Purposeful sampling was described by Merriam (1998) as “Purposeful sampling is based on the assumption that the investigator wants to discover, understand, and gain insight and therefore must select a sample from which the most can be learned (p.61). In order to select the participant that the most can be learned, two phases were processed. The first phase is: At the beginning of the semester, electrochemistry content test was conducted to the 16 pre-service chemistry teachers who were enrolled the practice teaching course in chemistry education program. The electrochemistry content test comprised of fifteen questions including open-ended, true-false and fill in the blank types of questions. The details of content test was provided in the data collection part. Based on the grades taken from the electrochemistry content test, pre-service were categorized regarding their content knowledge level on electrochemistry. Then I talked with the pre-service teachers who were in the low content knowledge group and high content knowledge group in order to explain the purpose and the requirements of the study in addition to course requirements. Then I chose two pre-service teachers for the study who both volunteered to participate in the study and would provide information rich cases. Both of them signed a consent form informing them about the research.

The second phase is related to decide the school where pre-service teachers will be assigned. This research was conducted through the practice teaching course and during this course pre-service teachers are supposed to experience teaching practice both at faculty of education and cooperating high school. The details of the course would be explained in the context of the study part. Based on the number of participants enrolled to the course, pre-service teachers were assigned two cooperating high school. At the beginning of the semester, I talked the teachers in both cooperating high schools about my study before I chose the school. Due to lack of time to cover curriculum, teachers were reluctant to give their lessons to pre-service teacher to gain teaching experience. Teachers working in one of the cooperating high school gave permission to pre-service teachers to teach electrochemistry at 11^{th} grade instead of them. After dealing with teachers, I took their schedule. Two out of three chemistry teachers taught at 11th grade so only two pre-service teachers and two chemistry teachers schedule matched so I studied with two pre-service teachers. Then two pre-service teacher were assigned to the same cooperation high school.

The participants for the study were two pre-service chemistry teachers (two females, Zeynep and Defne) who were enrolled in course namely "Practice Teaching in Science Education Course" during the 2013-2014 spring semester. Two of them were in their last semester of a 5-year chemistry teacher education program that offers a master's degree without thesis and these pre-service teachers were supposed to graduate at the end of the 2013-2014 spring semester. Both of them had similar background in terms of coursework. Before the practice teaching in science education course, both of them completed the courses including subject matter courses (e.g. general chemistry and organic chemistry), pedagogical courses (e.g. development and learning) and subject specific pedagogical courses (e.g. methods of science teaching and instructional technology and material development). At the time of the study, Zeynep and Defne had CGPAs of 2.86 and 2.30 (of 4.00) respectively.

3.4 Topic selection

Electrochemistry has been accepted as one of the most difficult chemistry topics for students to learn and for teachers to teach (De Jong & Treagust, 2002), and both teachers and students had a wide a range of misconceptions in electrochemistry. Several studies reported that students have misconceptions and difficulties in electrochemistry (Acar & Tarhan, 2007; Ekiz, Kutucu, Akkus & Boz, 2011; Garnett & Treagust, 1992a; 1992b; Ogude & Bradley, 1994; Ozkaya, 2002; Sanger & Greenbowe, 1997a; 1997b; Schmidt, Marohn & Harrison, 2007).

Moreover, electrochemistry is a crucial topic in chemistry due to the fact that it has wide range of daily life applications such as batteries, electroplating, corrosion and so forth. Also the place of electrochemistry in the curriculum also important, electrochemistry has links to chemical equilibrium, types of reactions and thermodynamics (Rollnick & Mavhunga, 2014)

Furthermore, in terms of teaching electrochemistry, there have not been so much studies (Aydin, 2012; Rollnick & Mavhunga, 2014) and De Jong and Treagust (2002) called for the research pertained to teaching of electrochemistry.

In chemistry curriculum at 11th grade the sequence of the topics are energy and chemical change, reaction rate, chemical equilibrium, electrochemistry and radioactivity. In the fall semester, first two topic and half of chemical equilibrium, in the spring semester the other half of chemical equilibrium and the last two topic were taught. The topic selected had to be in the spring semester due to the fact that science teaching experience course was opened with enough participants in spring semester. So from the 11th grade curriculum, I chose electrochemistry to investigate pre-service teachers PCK and the interaction between their PCK and CK.

3.5 Context of the study

One of the important characteristics of qualitative research is that researchers observe the behavior of participants in their real settings (Merriam, 1998) Hence, in this study the real setting is the classroom environment in the cooperating high school. Data were collected during the teaching experience at cooperating high school that is a public high school in Ankara. The total number of students in the high school was 680. The age range of students are 15 to 18 years old in secondary level of high school. Furthermore, there were four chemistry teachers in the high school. The classrooms that pre-service teacher enacted their instruction had approximately 30-35 students. The classrooms that pre-service teacher experienced their teaching had smart boards and internet connection. Although the high school had a chemistry laboratory, they didn’t have adequate equipment and chemicals so pre-service teachers supplied the needed laboratory equipment and chemicals for their demonstration from the university.

3.6 Data Collection and Data collection sources

There have been various ways to collect data in qualitative research, especially for case study Cresswell (2007) proposed documents, audiovisual materials, observation, and interviews as data collection approaches in qualitative research.

To investigate how pre-service teachers' PCK and CK interacts while teaching electrochemistry, data were collected via CoRe, semi-structured interviews and video stimulated recall interview, and observation. Pedagogical content knowledge construct is a complex and has internal nature so it is comprised of what a teacher knows, what a teacher enacts during instruction and the underlying reasons of instructional decisions hence PCK cannot be identified using merely one type of data such as observation or interview (Baxter & Lederman, 1999). Baxter and Lederman advocated that "…an observation would not reveal why the teacher chose to use some examples while avoiding others. Observations provide only a limited view of pedagogical content knowledge; we must ask teachers to articulate their knowledge."(p. 148). Hence, multiple data sources were used to collect rich and in-depth data about pre-service teachers' PCK and, PCK and CK interaction during the study. The timeline of the data collection process was provided in
Figure 2.

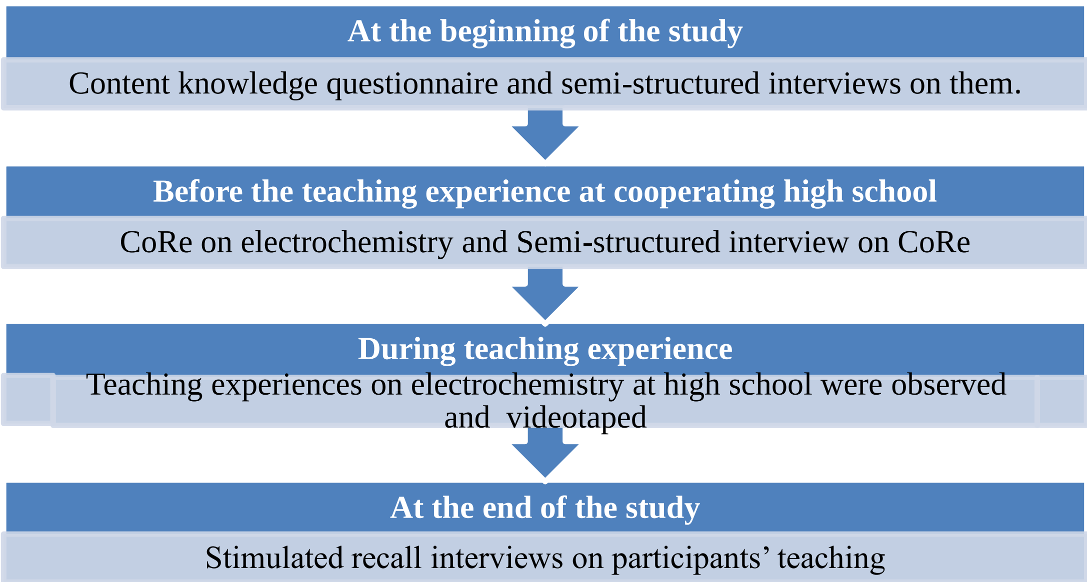


Figure 2. Data collection timeline

3.7 Details about the Data Collection Instruments

3.7.1 CoRe

PCK has a tacit nature and it is difficult for teachers to explicate their reasons of their instructional decisions behind their teaching activities (Loughran, Milroy, Berry, Gunstone & Mulhall, 2001). CoRe presents a chance for teachers to make their practice explicit. CoRe has two functions according to Loughran et al., (2004): a research tool to capture science teachers' understanding of the content and science teachers' way of representing this content. CoRe is a kind of form that represents pre-service and in-service teachers' PCK as "it [CoRe] links the how, why, and what content to be taught with what they agree to be important in shaping students' learning and teachers' teaching" (Loughran, Berry & Mulhall, 2012). The horizontal axis of the CoRe includes big ideas that teachers see as important to learn for students and the vertical axis includes specific information regarding big ideas that impact teachers' instruction.

In this study, CoRe was used as a lesson planning format for their instruction at cooperating high school. I also utilized CoRe to identify the interaction between pre-service teachers' PCK and CK. Due to the study was conducted with the pre-service teachers enrolled in practice teaching course, the revised form of CoRe (Aydin et al., 2013) was used in this study. There have been some changes between the original one (Loughran et al. 2004) and the revised one. The revised prompts and their previous version in the original CoRe are presented in Table 2. CoRe that was used in the study was provided at Appendix A.

Table 2. Revised prompts and original prompts in CoRe

Original prompts of CoRe (Loughran et al. 2004)	**Revised CoRe (Aydın et al. 2013)**
1. What you intend the students to learn about this idea?	What concepts/big ideas do you intend students to learn?
	What do you expect students to understand about this concept and be able to do as a result?
2. Why it is important for students to know this?	Why is it important for students to learn this concept?
3. What else you know about this idea (that you do not intend students to know yet)?	As a teacher, what should you know about this topic?
4. Difficulties/limitations connected with teaching this idea	What difficulties do students typically have about each concept/idea?
5. Knowledge about students' thinking which influences your teaching of this idea	What misconceptions do students typically have about each concept/idea?
6. Others factors that influence your teaching of this idea	*Exclude this prompt*
7. Teaching procedures (and particular reasons for using these to engage with this idea).	Which teaching strategy and what specific activities might be useful for helping students develop an understanding of the concept?
8. Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of responses).	In what ways would you assess students' understanding or confusion about this concept?
	What materials/ equipment are need to teach the lesson?

3.7.2 Interviews

Qualitative researchers usually utilize interviews during data collection process (Marshall & Rossman, 2006) Interviews provide valuable information regarding participants' point of view, feelings, and goals which cannot be observed directly (Patton, 2002). The interviews conducted in this study included questions that were open-ended and semi-structured. Semi-structured interviews comprised of "..a mix of more and less structured questions" (Merriam, 1998, p.74). There were different types of interviews conducted in this study which are content knowledge interview, CoRe interview and stimulated recall interview (See Table 3).

Table 3. Detailed information about interviews conducted

Types of interview	Purpose of the interview and method	Time
Content knowledge interview	**Purpose :** To gain detailed knowledge about pre-service chemistry teachers' electrochemistry content knowledge and to clarify the responses to questions at the electrochemistry content test **Method:** Semi-structured interview	After conducting the electrochemistry content test. It took between 30-40 minutes.
CoRe Interview	**Purpose:** To delve into the underlying reason of pre-service teachers' planning and teaching. Also participants were asked about their PCK and how PCK interacted their CK during the planning. **Method:** semi-structured interview	After participants prepared the CoRe. It took about 80-90 minutes.
Interview on their teaching (stimulated recall interview)	**Purpose :** to gain insight into why pre-service teachers chose to enact and teach in certain ways, and how their PCK and CK interacted during their teaching **Method:** stimulated recall interview using video recordings	After enacting their instruction. For each lesson, the interview took approximately 60 minutes.

Content knowledge interview aimed to explore pre-service teachers' electrochemistry content knowledge. The interview questions were prepared in the light of the responses of pre-service teachers to electrochemistry content test. As it will be mentioned in the content knowledge test part, the test included fifteen questions that focused on redox reactions, galvanic cell, concentration cell, standard hydrogen electrode (SHE), electrolytic cell and concepts included in electrochemistry topic. During the interview, the missing part or nebulous part of the pre-service teachers' responses given in the electrochemistry content test were emphasized to clarify their understanding of electrochemistry concepts. Content knowledge interview was conducted just after the electrochemistry content test and lasted 30- 40 minutes approximately for each pre-service teacher.

Regarding the CoRe interview, semi-structured interviews were conducted after the pre-service teachers prepared their CoRes on electrochemistry. The aim of this interview was to gain insight about pre-service teachers' reasoning about their instructional decision regarding their instruction and their planning. Interview questions were prepared based on the CoRe developed by pre-service chemistry teachers. For instance, pre-service teacher wrote the CoRe big ideas related to her instruction during the interview it was asked as "How did you determine your big ideas?" or pre-service teacher mentioned in her CoRe that she would use informal questioning as formative assessment so it was asked the reason why she preferred to use informal questioning. All interview questions asked during the interviews were provided in Appendix B.

3.7.2.1 Stimulated recall interview

Stimulated recall interviews give an opportunity to clarify teachers' decision making process associated with their teaching practice (Dempsey, 2010; Nguyen, McFadden, Tangen, & Beutel, 2013). Jensen and Winitzky (2002) mentioned that stimulated recall interviews provided far more insight in order to elicit pre-service teachers' conceptions on their own teaching and lead pre-service teachers to reflect their views on their own practice. Stimulated recall interview has been used in growing number of studies to gain insightful and useful data and facilitate pre-service teachers and teachers learning from their own teaching experiences (Nilsson, 2008; Schepens, Aelterman & Van Keer, 2007; Lutovac, Kaasila, & Juuso, 2015; Freitas, Jiménez, & Mellado, 2004; Stough, 2001; Jensen & Winitzky, 2002). Hence, stimulated recall interview was chosen as a main data source for this study to enhance pre-service teachers' reflections about their instruction and to examine the knowledge bases interaction namely, PCK and CK interaction, underlying the classroom actions of pre-service chemistry teachers.

Stimulated recall interview gave pre-service teachers a chance to view themselves while teaching and helped them to recall their thoughts of instructional events that occurred during their instruction hence this led them to make explicit their thinking and underlying reasons of teaching practice. During their electrochemistry teaching at high school, all their instructions were videotaped with the permission of pre-service teachers. After then their teaching completed, the pre-service teachers' reflections and instructional decisions were elicited through an interview while watching their video recordings in the classroom with the researcher. During the interview, as it was advised (Nguyen et al. 2013; Dempsey, 2010) interview protocol was used that was developed by researcher after watching four hour instruction and identifying all the important points in the instruction in terms of PCK components and, interaction between CK and PCK for each pre-service teacher specially. Several examples for the interview questions are as: "Why did you choose this (e.g., 5E [engagement, exploration, explanation, elaboration, and evaluation] learning cycle) teaching strategy in your instruction? " Why did you prefer to use this analogy/representation/ animation (e.g., sea-level analogy) in your instruction?" "Why did you refer chemical equilibrium during your instruction? How did improve your students' understanding of electrochemistry?" "Why did you emphasize the misconception regarding the identification of anode and cathode in galvanic cells while teaching electrochemistry?". As an example stimulated recall interview questions for Defne's one hour teaching was provided in Appendix C. All the interviews were audio recorded with the permission of pre-service teachers using a digital voice recorder and transcribed verbatim.

Although stimulated recall interview has intense and time consuming nature, it provides valuable information and insight about implicit theories and belief, and interaction of them in action which are closely related to pedagogical content knowledge (Meade & McMenimam, 1992).

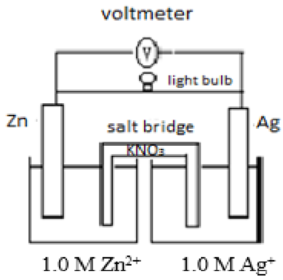
3.7.3. Observations

Observation has a crucial role in qualitative studies and is used to explore complex interactions in natural field settings (Marshall & Rossman, 2006; Merriam, 1998). Observation was one of the main data sources for capturing pre-service teachers' PCK and the interaction between PCK and CK while teaching electrochemistry in a real classroom environment in a high school. During the observation, I took field notes in terms of what is going on in the classroom. The field notes are comprised of what researcher hears, sees, experiences and thinks during the observation (Bogdan & Biklen, 1998). However, too much events are going on during the enactment of instruction so field notes are limited whatever an observer could note (Stigler, Gallimore, & Hiebert, 2000). On the other hand, video records of classroom lessons provide opportunity to researchers to capture the events more detailed and analyze the complex interaction occurred during the lesson (Stigler et al., 2000) in other words utilizing video supplies to collect "naturally occurring data" (Jewitt, 2012) . All teaching practice of pre-service teachers were video recorded. For each pre-service teacher, their teaching on electrochemistry was observed and recorded during four lessons with the permission of the pre-service teachers and teachers at the high school. In addition, video records can be paused or watched again and used for video stimulated recall interviews.

3.7.4. Content knowledge test

Electrochemistry content test was comprised of fifteen questions including open-ended questions, true-false items and fill in the blank types of questions. Aim of this test was to investigate pre-service teachers' understanding on electrochemistry qualitatively rather than quantitatively. The content test was developed utilizing the related literature (Acar & Tarhan, 2007; Garnett & Treagust, 1992b; Huddle, White & Rogers, 2000; O' Grady-Morris, 2008; Ogude & Bradley, 1994; 1996; Sanger & Greenbowe, 1997a; 1997b; Yürük, 2007). The questions were determined taking into account the most common misconceptions the both teachers and pre-service teachers have on electrochemistry and the objectives presented in the 11th grade chemistry curriculum. The electrochemistry content test focused on the main concepts in electrochemistry as follows: redox reactions, galvanic cells, standard hydrogen electrode, concentration cells, electrolytic cells, electrolysis. In addition to main concepts of electrochemistry, daily life applications of electrochemistry and questions that required algorithmic calculations were also included. A few examples of test items are shown in Figure 3.

Regarding internal validity, the electrochemistry content test and table of specification of this test were sent to five experts who are studying in chemistry education. All the experts examined the questions and sent back their feedbacks. In the light of experts' feedback, the electrochemistry content test was revised and took its final form. The electrochemistry content test was provided in Appendix D.



14. Evaluate whether the following claim and reason are **Correct** or **Incorrect**. Then please provide a detailed explanation for the answer you have chosen.

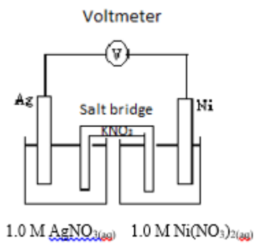
Claim	*Reason*
If the salt bridge in the picture above was replaced by a copper wire (an electrical conductor), the light bulb would be lit.	There will be a continuous flow of electrons in the electrolyte solutions that can pass through the copper bridge

Claim is correct / incorrect because………..

Reason is correct / incorrect because…………

13. Cars in coastal cities are more prone to rust. Why? Please provide a detailed explanation for your answer.

8. Please answer the following questions according to electrochemical cell drawn below.



The salt bridge contains $KNO_{3(aq)}$

$Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$, $E^{o} = +0.80V$

$Ni^{2+}(aq) + 2e^{-} \rightarrow Ni(s)$, $E^{o} = -0.25V$

a) What is the cell potential of this cell? Please show your work.

b) What is the overall reaction for this cell? Does the redox reaction taking place in this cell occur spontaneous or nonspontaneous? How would you decide this? Please explain your answer.

Figure 3. Extract of sampe test items in the electrochemistry content test

3.8 Pilot Study

The aim of the pilot study was to test the instruments and get feedback regarding the instruments, and identify the errors before conducting the main study (Marshall & Rossman, 2006). In addition, pilot study gave a chance to revise the data collection tools and the research process. For the content test, I conducted the first version of electrochemistry content test to 8 pre-service chemistry teachers at 4^{th} grade at chemistry teacher education program during 2013-2014 fall semester. Then, after the content test was conducted I talked with them unofficially about the unclear part of the test. Based on the results of the test and feedbacks gathered from the pre-service teachers, some items of the test were excluded and some of them were revised. Regarding the interview questions, I requested one pre-service chemistry teacher enrolled in practice teaching course after her second microteaching session on "chemical equilibrium" on the faculty of education. It was useful for me for making required changes in the interview questions in the parts that may cause difficulty in understanding and anticipate the range of responses to the questions taken from pre-service teachers.

3.9 Data Analysis

3.9.1 Data Analysis for Content Knowledge

The content test was comprised of open-ended questions and true-false items. The responses for the open-ended were categorized as scientifically correct, partially correct, incorrect and no response. Correct answer should include a depth understanding about the topic and the relationship between the concepts of the topic. Partially correct refers to the response containing some information but including misconception or inaccurate information. Incorrect response means the response is inadequate, contains misconception or irrelevant information. No response is the area of answer that was left blank. (see Table 4)

Table 4. Examples of scoring rubric for content knowledge test

Score	Description	Example
Correct (3 pts)	The participant indicate a depth understanding about the topic and the relationship between the concepts of the topic	In the electrochemical cell, electron enter the solution from the anode, travel through wire, and emerge at the cathode.
Partially correct (2 pts)	The response including some details but not well developed, and includes some misconceptions or some inadequacies information.	In the electrochemical cell, electron enter the solution from the anode, travel through the solution and the salt bridge, and emerge at the anode to complete the circuit.
Incorrect (1 pts)	The response is inadequate, contains misconception or irrelevant information	In the electrochemical cell, electron enter the solution from the cathode, travel through the solution and the salt bridge, and emerge at the anode to complete the circuit.
No response (0 pts)	Left blank	

3.9.2 Data Analysis for Nature of PCK

Firstly, all video recordings were watched and taken notes regarding the crucial parts of pre-service teachers' instruction on electrochemistry again. Then all the interviews were transcribed and data coding started. In this study, pre-service chemistry teachers' PCK were analyzed based on the Magnusson et al. (1999) PCK model mainly but in the light of related literature and data collected the PCK model was modified (see

Table 5). Utilizing the components and their corresponding subcomponents presented in the table, each pre-service teachers' responses were coded.

Table 5. Components of PCK used in the study (Modification of Magnusson et al. 1999; Park & Oliver, 2008; Friedrichsen & Dana, 2005)

Science teaching orientation (STO)	• Central goals • Peripheral goals
Knowledge of student understanding of science (KoL)	• Misconceptions • Learning difficulties • Prerequisite knowledge

Knowledge of Instructional strategies (KoIS)	• Knowledge of subject specific strategies
	• Knowledge of topic specific strategies
	  o Representations (example: Illustrations, examples, models, or analogies)
	  o Activities (ex: Problems, demonstrations, simulations, investigations or experiments)

Knowledge of Curriculum (KoC)	• Knowledge of Goals and objectives • Vertical Curriculum • Horizontal curriculum • Relating to other disciplines • Knowledge of specific curricular programs • Curricular Saliency • Altering the curriculum
Knowledge of Assessment (KoAs)	• Knowledge of dimensions of science learning to assess (What to assess) (ex: Conceptual understanding, interdisciplinary themes, nature of science, scientific investigation and practical reasoning) • Knowledge of methods of assessment (how to assess)

Regarding orientation towards science teaching, Magnusson et al. (1999) proposed nine different teaching orientation namely: process, academic rigor, didactic, conceptual change, activity-driven, discovery, project-based science, inquiry and guided inquiry. The research studies in the literature on science teaching orientation could not reach consensus on nine orientation types. Researchers mentioned that teachers did not have a single orientation merely, but held two or three orientations at the same time (Friedrichsen& Dana, 2005). Pre-service teachers' science teaching orientations were examined on two dimensions: central and peripheral goals as proposed by Friedrichsen and Dana (2005). Central goals were defined as dominated goals that affect teachers' instructional decisions directly. On the other hand, peripheral goals had less impact on teachers' decision making process pertained to their teaching (Friedrichsen & Dana, 2005). Furthermore, these goals were categorized as affective domain goals, schooling goals and subject matter goals are mentioned as Friedrichsen & Dana (2005). Schooling goals refer to students' being successful in school and life, being informed citizens. Affective goals are based on developing attitude towards science, curiosity and ethics. Subject matter goals were related to developing conceptual understanding. Regarding the analyzing of other PCK components and sub-components, the data collected via CoRe, interview, stimulated recall interview and observations were analyzed taking into consideration of the pre-established categories indicated in Table 5

3.9.3 Data Analysis for Content knowledge and PCK interaction

After coding the pre-service teachers' PCK and CK, I became more familiar with the whole data. I coded all the interactions detected in the data sources but especially in data collected by video stimulated recall interviews. It was determined how to decide if an interaction between content knowledge and PCK components existed in the data. For example, pre-service teacher preferred to use discussion while explaining, whilst in the electrolytic cell sub-topic she preferred lecturing and avoiding asking questions and discussion due to lack of content knowledge in electrolytic cell. In this way, I constructed Table 6 including categories and examples.

Table 6. Categories for analyzing data and explanations

PCK component interacted with CK	Explanation
CK – KoIS interaction	If pre-service teacher chose appropriate/ inappropriate subject specific strategy and effective usage of this strategy based on his/her content knowledge.
	If pre-service teacher chose appropriate/inappropriate topic specific instructional strategy in terms of representations and activities and effective usage of this strategy based on his/her content knowledge.
CK- KoL interaction	If pre-service teacher used his/her content knowledge to identify and remedy students' difficulties and misconceptions.
	If pre-service teacher used his/her content knowledge to identify students' prerequisite knowledge.
CK-STO interaction	If pre-service teacher used his/her content knowledge to determine his/her goals and purposes for science teaching.
CK- KoAs interaction	If pre-service teacher determined the concepts that are important to assess or not utilizing his/her content knowledge (what to assess)
	If pre-service teacher determined appropriate/inappropriate assessment methods to assess students' understanding or prior knowledge based on his/ her content knowledge (how to assess)
CK- KoC interaction	If pre-service teacher made changes in curriculum utilizing her/his content knowledge
	If pre-service teacher made vertical or/and horizontal relations to use what students know about the topic from previous courses or will learn in next courses at the same and different grades during his/her instruction based on his/her content knowledge.
	If pre-service teacher changed the sequence the order of teaching utilizing his/her content knowledge
	If pre-service teacher associated the concept with other disciplines utilizing his/her content knowledge.
	If pre-service teacher determined objectives from curriculum considering his/her utilizing his/her content knowledge.

Considering the categorization, tables were formed for each pre-service teacher and tables were compared and contrasted in order to identify any difference between pre-service teachers in terms of the interaction of PCK and CK. Cross-case analysis indicated that the interaction between PCK components and CK were differentiated in some components regarding the content knowledge level of pre-service teachers. Detailed examples were given in result part.

3.10 Trustworthiness

While validity and reliability issues are the indicators of quality in quantitative studies, the trustworthiness that was introduced by Lincoln and Guba (1985) is the indicator of quality in qualitative studies. Lincoln and Guba (1985) defined alternative terms that are more appropriate to the naturalistic research. In order to establish trustworthiness of a study, Lincoln and Guba (1985) mentioned unique terms namely " credibility" "transferability" "dependability" and "confirmability" as the naturalist's equivalents for these terms are " interval validity," " external validity," " reliability,"and " objectivity" respectively (p. 300). They proposed different techniques in order to operationalize these new terms pertained to validity and reliability issues in qualitative research. In the following part how trustworthiness of this study supplied were given.

3.10.1 Credibility

Credibility in qualitative research is associated with how findings of the study parallel with reality (Merriam, 1998). Marshall and Rossman defined credibility as "..in which the goal is to demonstrate that the inquiry was conducted in such a manner as to ensure that the subject was appropriately identified and described" (p. 201). There have been several strategies to improve credibility of qualitative research studies namely triangulation, member checks, long-term observation or prolonged engagement, peer examination or peer debriefings, participatory or collaborative modes of research and clarifying researcher's biases(Merriam, 1998; Creswell, 2007) . In this study, triangulation, member check, peer debriefings, and prolonged engagement were used to ensure credibility.

Triangulation refers using multiple and different sources of data, investigators and methods in an investigation to gain a holistic understanding regarding the themes (Creswell, 2007). Patton (2002) identified four types of triangulation as: triangulation of sources, investigator/analyst triangulation, theory/perspective triangulation, and methods triangulation.

Triangulation of sources and investigator triangulation were used in this study. In order to supply triangulation of sources, multiple data sources including CoRe, field notes from observation, interviews and electrochemistry content test were used. Investigator triangulation was achieved by inviting one of my colleague, who was familiar with PCK construct, PCK literature in order to observe pre-service teachers' instruction. One out of four-hour instruction of each pre-service teachers were observed by me and my colleague in the real classroom environment. After observation, we came together to discuss regarding observation. If there was any incongruent parts, they were solved by negotiation. Furthermore, taking video recordings of pre-service teachers' all instructions provided an opportunity to watch several times by me and an additional researcher to support triangulation. For instance, while preparing stimulated recall interview questions, a researcher and me watched one hour of video recordings of pre-service teachers' instruction and determined the crucial excerpts of the instruction independently and, discussed and reached consensus.

Peer debriefing involves a person to review and interpret the findings (Merriam, 1998), in other words it offers "an external check of the research process" (Creswell, 2007). I consulted two of my colleagues who had experience in qualitative research and PCK during collecting, coding, analyzing and commenting the findings.

Prolonged engagement refers gathering information for a period of time. This provides to build trust with participants that leads to increase the validity of results of the study (Creswell, 2007; Meriam, 1998) Although I observed participants' electrochemistry instruction during four hours at the cooperating high school, I was both a researcher and teaching assistant of the practice teaching at science education course hence I observed all their instruction both at faculty of education and cooperating high school, spent time with them and talked about their instructions. I spent one semester approximately 14 weeks with these participants.

Member check is returning the participants by whom the data were obtained to ask them about the credibility of the findings and conclusions (Creswell, 2007; Merriam, 1998). Lincoln and Guba (1985) articulated member check to be "the most critical technique for establishing credibility" (p.314). The pre-service chemistry teachers were given a chance to react to the interpretation of the data during the study. For instance, during the stimulated recall interview, the researcher's interpretation of the pre-service teachers' teaching and instructional decisions on electrochemistry was discussed with participants in detail and their own comments were taken. After analyzing the data, it was shared with participants about the summary of their PCK and the interaction of CK and PCK on electrochemistry to check the data and interpretation.

Furthermore, the experience of researcher in qualitative research was also important in terms of credibility (Patton, 2002). Before this study, I took qualitative research course and participated in several research studies on PCK of pre-service teachers.

3.10.2 Dependability

In quantitative studies, reliability issue depends on a single reality and the findings of the research can be repeated. On the other hand, in qualitative research, findings of the research cannot be replicated due to the nature of person behavior (Merriam, 1998). In qualitative research the main point regarding dependability is "…whether the results are consistent with the data collected" (Merriam, 1998, p.206). To increase dependability, there are several techniques that was also used in credibility namely: data triangulation and investigator triangulation. Both of them used in the current study was mentioned in the credibility part. Furthermore, stimulated recall interview accompanied with videos "…have a satisfactory degree of reliability for obtaining data about the thoughts participants had while performing that task" (Henderson & Tallman, 2006, p. 75). During the study, two researchers who have experience on PCK, chemistry education and qualitative research coded the data collected from one of the pre-service chemistry teachers.

Interrater reliability was calculated utilizing the formula proposed by Miles and Huberman (1994) as following:

$$\text{Reliability} = \text{Number of agreements} / (\text{Total number of agreements} + \text{disagreements}) \times 100$$

The interrater reliability was calculated as %90.

3.10.3 Transferability

Transferability concept also refers to generalizability. Transferability mentions to the extent to which researchers research questions can also be applied to another context (Lincoln & Guba, 1985) Due to the nature of qualitative research, researchers are supposed to explain the whole process and describe the context rich enough as called thick description, by this way other researchers are able to decide regarding the findings of the study to what extent to transfer to different settings or context (Patton, 2002). The participants, chemistry education program, the course that data were collected and the context were described in detail.

3.11 Keywords and Databases Searched

Keywords were determined with the help of previous studies and reviews on the related topic on the literature. The initial keywords were as following: PCK, CK, pre-service teachers, pre-service chemistry teachers, chemistry education and science education. Then, Science Direct, Educational Resources Information Center (ERIC), ProQuest (UMI) Dissertations & Theses, METU Library Theses and Dissertations, and Turkish Higher Education Council National Dissertation Center databases were searched with keywords for the relevant primary sources. Various journals having online access were also searched to reach the primary sources in Turkey such as Elementary Online, Education and Science, Gazi University Journal of Education and so forth. In addition to databases, the books were searched with keywords in university libraries (e.g., Middle East Technical University, University of Georgia) to reach as much sources as possible. As it was known, literature review is an ongoing process so

I regularly reviewed related literature and if I came across different sources during the study, they were put into the study.

3.12 The Role of the Researcher

In qualitative researches, the researcher is the key instrument (Marshall & Rossman, 2006). Patton (2002) developed a series of ranges regarding the role of researcher in qualitative research namely: participantness, revealedness and, intensiveness and extensiveness.

The range of participantness differs from full participant to complete observer. In this current study, I was a complete observer and did not participate in pre-service teachers' teaching or any discussion, demonstration during their instruction. I was just present at the classroom and took video recordings and field notes regarding the pre-service teachers' teaching, questions, students' responses to these questions and any other details related to instruction.

Revealedness is about informing the participant about the study that is going on (Marshall & Rossman, 2006). At the beginning of the study, participants were informed about the purpose and requirements of the study. Also, participants voluntarily participated in the study and signed the consent form.

Intensiveness and extensiveness is pertained to the amount of time spent in the research setting. As I mentioned before, although pre-service teachers' instruction regarding electrochemistry at the cooperating high school took two weeks, I spent one semester with the participant. I have been a teaching assistant for six years and I have met these pre-service teachers as a teaching assistant for different courses before this course. This gave an opportunity to build trusting relationships with the participants which improved the quality of qualitative data in terms of building deep interaction providing idiosyncratic understanding (Toma, 2000)

3.13 Negotiating Entry

The participants were selected from whom were enrolled in the “Practice Teaching in Science Education” course which is a must course in chemistry education program. After electrochemistry content test was conducted to identify the content level of pre-service teachers participated in the course, the potential participants of the study were informed about the purpose and requirements of the study honestly and the participants voluntarily participated the study.

3.14 Ethical Considerations

During this research, ethical considerations were taken into account. Firstly, Institutional Review Board (IRB) permission was taken before the study began (Appendix E) IRB approved that the study has no potential risk or harm for participants. Anonymity of the participants and the university were ensured. Pseudonyms were used for all the participants. The participants participated in the study voluntarily and signed an informed consent form including the purpose of the study. In addition at the beginning of the study and during data collection process, participants were informed about the purpose of the study and purpose of collecting the information verbally. Regarding confidentially of data, only the researcher, her advisor and additional coder had access to the data collected. Patton (2002) proposed some items to be considered pertained to ethics in qualitative research namely “ explaining purpose of the inquiry and method to be used, promises and reciprocity, risk assessment, confidentiality, informed consent, data access and ownership, interviewer mental health, advice, data collection boundaries and ethical versus legal conduct” (pp.408-409). Hence, deception of participants, protection of participants from harm and confidentially of data were supplied for this study to ensure ethical consideration.

3.15 Limitations about Trustworthiness of the Study

All research projects have limitations and Patton (2002) stated that “There are no perfect research designs. There are always trade-off” (p. 223) there were two limitations of this study. First one was pertained to being of researcher at the classroom during the instruction. In addition, all the instructions of participants were video recorded. This situation may affect participant behavior. As I mentioned before, participants were enrolled in practice teaching course at the same time and during this course they were supposed to prepare instruction at the faculty and these instructions were also video recorded. Hence, they were familiar to enact an instruction across the video cameras. Moreover, the researcher was also the teaching assistant of the course they were taken so the participants accepted me as a teacher rather than a researcher.

The second limitation was related to time limitation. Although I spent one semester with pre-service chemistry teachers and observed their instruction on different chemistry topics at both faculty and cooperating high school within practice teaching in science education course, I could observe participants' electrochemistry instruction for just two weeks (four hours). I tried to support this observation with video stimulated recall interview and capture their PCK and, PCK and CK interaction as much as detail.

3.16 Time schedule

Data were collected from two pre-service chemistry teachers enrolled a "Practice Teaching in Science Education Course" in a public university in Ankara. Table 7 indicates the timeline of the research.

Table 7. Timeline for the research

Date	Events
August 2012 – December 2012	Design of the study
January 2013- August 2013	Development of the interview questions and electrochemistry content test for data collection
September 2013- December 2013	Pilot study
January 2014- March 2014	Data analysis of pilot study and revision of the instruments
April 2014- June 2014	Data collection
July 2014- December 2014	Preparing data for the analysis
January 2015- December 2015	Data analysis
January 2016- September 2016	Writing results, conclusion and discussion section

3.17 Assumptions of the Study

- All the participants sincerely answered the questions
- Both of the pre-service teachers had little teaching experience

CHAPTER 4

RESULTS

4.1. Introduction of the Participants

The participants of this study were two pre-service chemistry teachers. Each of the pre-service teachers was different case due to level of their content knowledge. Zeynep and Defne were both enrolled in the practice teaching course in chemistry education program during 2013-2014 fall semester in a public university in Ankara. Both of them completed the same courses and classmates. Due to the data collection was conducted at the mid of the semester, both of the pre-service teachers had little teaching experience regarding various chemistry topics.

4.2 Results for Content knowledge on electrochemistry

As it was mentioned in the methodology part, the content test involved questions regarding redox reactions, galvanic cells, concentration cells, standard hydrogen electrode, factor affecting the cell potential, electrolytic cell and daily life applications of electrochemistry. When it was examined the responses given to these questions, Defne had inadequate content knowledge on electrochemistry. Concerning galvanic cell, she knew basic concepts as determining anode and cathode in galvanic cells, function of voltmeter and salt bridge, the direction of electron flow, and the mass changes occurs at each electrode, but she had some inadequacies in determining the charge of anode and cathode, writing shorthand notation of the cell, the flow of ions in the half-cells. Similarly the questions related to concentration cells, her responses to the questions were coded as partially correct due to including some details but not well developed as lack of reasons how to determine anode and cathode in concentration cell. During the interview, she mentioned that “I memorize as less concentrated half-cell is anode and the more concentrated one is cathode but I don't know the underlying reason" **(Content knowledge interview)**

Regarding electrolytic cells, she left blank the questions related to electrolytic cells and algorithmic calculations on electrolysis. In the content knowledge interview she stated that she didn't have even basic knowledge as determining anode and cathode in electrolytic cells. Her explanations to questions includes some misconceptions or some inadequacies information. For instance, there was a question related to a common misconception of learners in electrochemical cells as:

> "Think that you are a chemistry teacher. While you are teaching electrochemistry one of your students, Ahmet, claimed "In the electrochemical cell, electron enter the solution from the cathode, travel through the solution and the salt bridge, and emerge at the anode to complete the circuit."

She answered this questions as:

> "I disagree with Ahmet. In electrochemical cell, we apply some energy from outside. In anode cell, oxidation occurs, in cathode cell reductions occurs. e^- travels through anode to cathode by the help of wire not salt bridge."

And correct explanation for this claim as written as "in the electrochemical cell, e- enters the solution from the anode to cathode and complete the circuit by the help of wire." This response shed light on the content knowledge of Defne on galvanic cell. She knew basic knowledge regarding the redox reactions occurring in galvanic cells but the reactions in the galvanic cell occurs spontaneously there is no need for external energy. Although she knew that there electron moves through anode to cathode, she had misconception as electron enters the solution so she thought that electron can flow through aqueous solution. In addition she knew that electron didn't move through salt bridge so she had some inadequacies and misconceptions in her content knowledge. Hence it can be concluded that Defne's content knowledge was weak on electrochemistry. Table 8 summarizes Defne's content knowledge of main concepts regarding electrochemistry.

Table 8. Defne's content knowledge of main concepts related to Electrochemistry

Concepts	**Answer of Defne**	**Category**
Redox reactions	She had difficulty in balancing the redox reactions	Partially correct
Galvanic cell	Standard reduction potentials can be measured independently without the use of other half-cell reactions with the known potential. Charge of anode is positive and charge of cathode is negative. Voltmeter measures the potential difference.	Partially correct
Concentration cell	Less concentrated is anode and more concentrated is cathode.	Partially correct
Standard hydrogen electrode (SHE)	SHE is reference for us, there is no importance.	Partially correct
Factors affecting cell potential	The cell potential is dependent of the metal used for the cathode and the concentration of the Cu^{2+} ions	Partially correct
Electrolytic cell	Left blank	
Daily life applications of electrochemistry	Batteries go dead because there is no potential difference between cells.	Correct

On the other hand, Zeynep responded correctly most of the questions regarding all the sub-topics of electrochemistry. She responded correctly all the questions regarding galvanic cell except determining the charges of electrode. Similarly, she responded correctly questions related to concentration cells. Regarding the electrolytic cells, she determined the anode and cathode utilizing the charge of the battery and discriminate electrolysis of molten and aqueous $AlBr_3$ but she had difficulty in determining what reactions are taking place at each electrode. She also had knowledge regarding the daily life application of electrochemistry. The question related to why batteries go dead she wrote that: “Potential difference drop and become equal while reactions run if there is no potential difference, batteries could not work”. Hence it can be concluded that Zeynep has robust content knowledge on electrochemistry. Table 9 summarizes Zeynep’s content knowledge of main concepts regarding electrochemistry.

Table 9. Zeynep’s content knowledge of main concepts related to Electrochemistry

Concepts	**Answer of Zeynep**	**Category**
Redox reactions	She balanced the redox reactions correctly.	Correct
Galvanic cell	Except the question regarding the determining charge of anode and cathode, she answered all the questions related to galvanic cell. “The function of salt bridge to provide electro neutrality”	Correct
Concentration cell	“The cell in the left is more concentrated so it much more difficult to form Cu2+ ions in it. So left is cathode, right one is anode.”	Correct
Standard hydrogen electrode (SHE)	“This is not possible to measure electrode potential of elements if reference point is not taken since SHE is a reference point for those measurements.”	Correct
Factors affecting cell potential	“The cell potential is dependent on the temperature”	Partially correct
Electrolytic cell	She determined the anode and cathode utilizing the charge of the battery.	Correct
Daily life applications of electrochemistry	“In coastal cities, air has a higher moist content which involve H20 in gas phase. Thus water molecules lead to rusting, taking place an oxidation reaction.”	Correct

4.3 PCK regarding Electrochemistry

4.3.1. Orientation to science teaching

Pre-service teachers' orientations to science teaching were presented as central and peripheral in general and then these goals were categorized as affective goals, schooling goals and subject matter goal as mentioned in Friedrichsen & Dana (2005). Both participants' orientation to science teaching included different types of goals namely subject matter, affective and schooling goals. So their orientation to science teaching did not comprise of a central and single component of orientation. When it was examined the Magnusson et al. (1999) perspective, Defne and Zeynep's orientation could not be labelled merely didactic or academic rigor in nature. Magnusson et al. (1999) defined the didactic orientation as the goal of transmitting the main concepts of science to learners and teachers who have this orientation generally use lecturing as an instructional method. On the other hand, academic rigor orientation was described as a goal to provide particular body of knowledge by Magnusson et al. (1999) and the characteristics of instruction is providing challenging and difficult problems to students, and also demonstrations to lead them to connect the science concepts and phenomena. When have a close look at pre-service teachers' instruction, both of them used lecturing mainly but they empowered their lecturing with analogies, demonstrations, animations and activities. In order to evaluate pre-service teachers' orientation to science teaching, data gathered through observations and video stimulated recall interviews were analyzed and summarized in tables following.

Table 10. Defne's goals concluded from interviews

Goals	**Central Goals**	**Peripheral goals**
To apply science to their daily life	Schooling goals	-
To develop positive attitude towards science	Affective goals	-
To prepare students for the university entrance exam	Schooling goals	-
To promote scientific literacy	Schooling goals	-

In order to identify Defne 's orientation to science teaching, she was asked to explain her reasons of teaching chemistry at high schools during the interview and she explained as following:

> "Chemistry is piece of science and in order to understand the nature of science, students should learn chemistry. I think teaching chemistry is a way of making student to love science…. Also chemistry is everywhere in our life. For instance, each day we drink water and the water is part of chemistry. Therefore in order to understand meaningfully what is happening in our life, chemistry should be learnt. Himm.. I think, every student should have certain amount of knowledge pertained to chemistry, physics and biology due to the fact that they may be interested in science in future". **(CoRe Interview)**

From this answer, it can be concluded that her central goal for teaching chemistry is to develop students' understanding about the relation between daily life and chemistry. By this way, students could develop a sense to understand what is happening in their surroundings. As an additional central goal, she held affective goal regarding to lead student to develop positive attitude towards science by understanding how science work. Therefore, Defne's held schooling goal and affective goal as central goals, however she did not have peripheral goals based on the interview results. (Table 10)

The other pre-service teacher Zeynep also has similar goals with Defne in terms of teaching science with one difference. Zeynep also has a goal pertained to prepare students to life in other words she aimed to help to gain an awareness on understanding and interpreting what happens in students' surrounding. (Table 11)

Table 11. Zeynep's goals concluded from interviews

Goals	**Central Goals**	**Peripheral goals**
To apply science to their daily life	Schooling goals	-
To develop positive attitude towards science	Affective goals	-
To prepare students for the university entrance exam	Schooling goals	-
To promote scientific literacy	Schooling goals	-
To prepare students to life	Schooling goals	-

In order to identify Zeynep's orientation to science teaching, she was asked to explain her reasons of teaching chemistry at high schools during the interview and she explained as following:

> "Firstly I would like to prepare students to the life. There are a lot of unknown things around us, there is a sense of wonder at human nature so as human we try to understand and make sense of what is happening around the world. Chemistry is very important to do this, not only to understand the nature of world but also the universe. One of my main purpose is to make students love science and use science to explain the events in their daily life. By this way they would be more aware of around them. Students should know chemistry in order to improve themselves and to be scientifically literate citizens"

Another question that was asked to pre-service teachers to examine their orientation towards science teaching was related to the importance of teaching electrochemistry. The interview dialogue conducted with Defne was as following:

> **R:** In your opinion, as a chemistry teacher why do you teach electrochemistry?
> **Defne:** Because electrochemistry is stated in the curriculum and they [students] are going to take university entrance exam so they should learn.
> **R:** Do you have another reason for teaching electrochemistry?
> **Defne: in** order to promote scientific literacy for them [students]
> **R:** Can you explain in detail?
> **Defne:** this [electrochemistry] is important because there are a lot examples from daily life. Students can understand batteries features which is used in daily life. In this way students can obtain scientific literacy.

Similar to the previous question she again emphasized the importance of preparing students to life by connecting daily life events to science that can be categorized as schooling goal. On the other hand, she highlighted the reality of Turkish Education system and the university entrance exam. Her another goal for teaching electrochemistry is subject matter goal in terms of providing electrochemistry content knowledge to students due to the curriculum and prepare them for the university entrance exam. During the interview, she did not concentrate on one of the goals, so both of them are assumed her central goals for teaching electrochemistry. Very similar to Defne, Zeynep also emphasized the importance of learning electrochemistry in terms of necessity due to university entrance exam, the place of electrochemistry in our daily life and account for the daily life application of electrochemistry as batteries and electroplating.

In addition to pre-service teachers' goals on science teaching identified through interviews, their electrochemistry instruction was also observed and these observations provided information related to their goals.

Table 12. Defne and Zeynep's goals deduced from their instructions

Goals	**Central Goals**	**Peripheral goals**
To provide conceptual understanding of chemistry	Subject matter goals	
To apply science to their daily life	Schooling goals	
To develop positive attitude towards science		Affective goals

Although during the interviews, I identified some distinctions between Zeynep and Defne's goals, their goals identified through the observation were very similar (Table 12). Participants' peripheral goals is detected as affective goal while there were not peripheral goal in the interviews. During their instruction, they mainly concentrated on providing the main concept to students by empowering their instruction with daily life applications of the topic. For instance, in Zeynep's instruction she presented videos regarding electroplating and electrolysis of sodium chloride solution in terms of commercial applications of electrolytic cells. Moreover, their peripheral goal was to lead students to develop positive attitude towards science teaching. For example, during Defne's instruction, she emphasized how science work and at the beginning of her instruction she explained the history of electrochemistry and indicated the tentativeness aspect of nature of science by giving examples from batteries.

4.3.2 Knowledge of learner

4.3.2.1 Pre-requisite knowledge

Zeynep was more aware of the pre-requisite knowledge that students should have to learn electrochemistry effectively than Defne. In the CoRe interview, Defne predicted some of the chemistry topic as prerequisite knowledge that students need in learning electrochemistry. She stated that students should know chemical equilibrium, redox reactions, solutions, and elements and compounds as pre-requisite knowledge however she ignored the basic concepts such as chemical reactions, chemical calculations, rate and heats of reactions. In addition to Defne's claim, Zeynep also mentioned that particulate nature of matter, phases of matter, chemical reactions and heat of reactions as prerequisite knowledge.

In term of pre-requisite knowledge, Defne mentioned the link within the electrochemistry. In Defne's CoRe, she mentioned that "If students don't know the meaning of anode and cathode, oxidation and reduction they cannot understand galvanic cell working principles" so she mentioned importance of learning the main concepts to learn the other concepts within the electrochemistry. She also stated that the function of salt bridge has an important role in understanding the working principles of galvanic and other cells. Zeynep also pointed the same connection within the electrochemistry topic during the interview. She stated that "…without knowing the redox reactions, students cannot grasp working principles of both galvanic and electrolytic cells" **(CoRe interview).**

During the instructions, while teaching factors effecting the cell potential, both Zeynep and Defne emphasized chemical equilibrium to explain these effects. They wrote a chemical equilibrium reaction on the board and discussed temperature and concentration effect utilizing this reaction. Although both of them aimed to make the new topic easier for student using the prerequisite knowledge, Defne achieved this superficially but Zeynep indicated how chemical equilibrium used to predict the effect of concentration change on cell potential. She wrote a chemical reaction and the equilibrium constant of this reaction on the blackboard. She wrote the following reaction:

$$A_{(s)} + B^{2+}_{(aq)} \leftrightarrows A^{2+}_{(aq)} + B_{(s)}$$

Zeynep wrote the constant of equilibrium as K= $[A^{2+}]/ [B^{2+}]$ and reminded students that while writing the equilibrium constant, the substance may be gases or molecules and ions in the solution.

4.3.2.2 Difficulties

Before teaching electrochemistry, both of the pre-service teachers mentioned common difficulties in electrochemistry that students may encounter in her CoRe utilizing related literature and self-experiences as a student at high school and university. For instance, Defne stated that students may have difficulty in understanding oxidation and reduction concepts in other words redox reactions. In addition, they had difficulty in using standard reduction potentials to predict anode and cathode. Defne also stated that learners are not able to distinguish the electrodes into anode and cathode with appropriate charges in galvanic cell. Zeynep mentioned that student may face problems in understanding how galvanic cell process work without applying external energy. Regarding concentration cell, both of the pre-service teacher mentioned that students find it difficult to understand electrodes are the same material and the electrolytes on the two half-cells involve the same ions. During the interview, both Defne and Zeynep mentioned the possible reasons for students to find electrochemistry hard to learn. Both of them emphasized how abstract nature of the topic affect student understanding so they cannot imagine how the cell work in microscopic level. For instance, Defne stated that owing to abstract nature of electrochemistry, students had difficulty in visualizing how electron flows through anode to cathode, how ions migrate, how oxidation and reduction occur. Defne deal with this difficulty with enriching the scientific explanation by using instructional representations as animations enabling students imagine what is happening when cell works in microscopic level. In addition, Defne stated that students had difficulty in using standard reduction potentials to predict anode and cathode. In order to handle this difficulty, Defne performed a few examples regarding determining anode and cathode.

The other pre-service teacher Zeynep also highlighted that "Students may have difficulty in visualizing the working principles of galvanic cell when we just explain verbally without enriching microscopic level representations". In order to handle this difficulty, similar to Defne, she used animation to help students visualize what is happening inside the galvanic cell. Furthermore, Zeynep also tried to draw students' attention to the possible difficulty before she came across during the instruction. During the interview, Zeynep stated that: "I read from related literature, students had difficulty in understanding concentration cell due to using the same electrode in both half-cells. They may think that by using the same electrodes in the cell could not produce potential difference. Hence, I especially drew students' attention by asking question as following; is it possible to produce potential difference by using the same electrodes?" (Stimulated recall interview). Besides this, Zeynep observed a difficulty during her instruction pertained to mass change of anode and cathode. Students had difficulty in identification of mass of which electrode increase or decrease. After she observed this, she tried to explain utilizing oxidation and reduction reactions.

Oxidation reaction (Anode) : $Al_{(s)} \rightarrow Al^{3+}_{(aq)} + 3e^-$ $E^0 = 1.66$ V
Reduction reaction (Cathode) : $Fe^{3+}_{(aq)} + e^- \rightarrow Fe^{2+}_{(aq)}$ $E^0 = -0.77$ V

Zeynep explained why mass of Al electrode will decrease and Fe electrode will increase using the half-cell reactions. **(Field note)**

4.3.2.3 Misconceptions

Before enactment of instruction, pre-service teachers prepared CoRe and stated the possible misconceptions compatible with related literature in electrochemistry. They utilized the studies conducted by Garnett and Treagust, (1992), Sanger and Greenbowe (1997a) and Garnett, Garnett and Hackling (1995). In the CoRe and interview, they mentioned the misconceptions which were in line with her big ideas. For instance, Defne stated that "Electrons enter the solution from the cathode, travel through the solutions and the salt bridge, and emerge at the anode to complete the circuit" and "The identity of the anode and cathode depends on the physical placement of the half-cells." In addition to similar misconceptions, Zeynep also stated that "In more concentrated side, there is an oxidation reaction takes place while in less concentrated side there is a reduction reaction takes place" and "Half-cell need not be electrically neutral. One half-cell can be positive and the other negative with an equal number".

Compatible with pre-service teachers' CoRe and interviews related to CoRe, they emphasized possible learners' misconceptions during the instruction. When the whole instruction was examined for each pre-service teacher, Defne mainly concentrated on the learners' misconceptions regarding galvanic cell sub topic. Electrolytic cells and concentration cells sub-topics were overlooked a little compared to galvanic cell. On the other hand, Zeynep tried to mention misconceptions regarding galvanic, concentration and electrolytic cells.

During the teaching, Defne warned students and tried to draw their attention regarding the possible misconception and provided scientifically correct explanation to students before she came across the misconceptions students might had. For instance, while explaining electrolytic cells, she indicated the drawing of electrolytic cell in the PowerPoint (Figure 4)

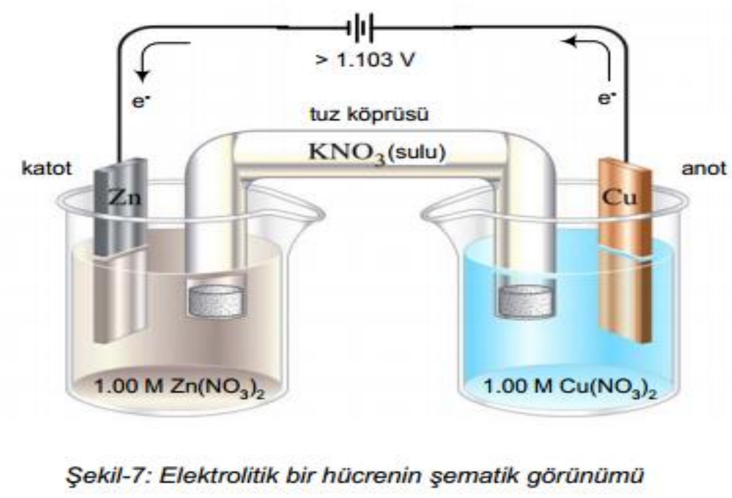


Figure 4. Drawing of electrolytic cell used in PowerPoint

> **Defne :** …Do you remember we made a demonstration related to galvanic cell in the previous lesson, Zn-Cu cell. When we consider the galvanic cell, Zn electrode is anode and Cu electrode is cathode. But if energy is applied to the galvanic cell, the process will reverse so Zn electrode is anode, Cu electrode is cathode. Because, the process of occurring in galvanic cell and electrolytic cell are reverse from each other….But the reaction occurring at anode and cathode does not change. Both in galvanic and electrolytic cells, oxidization reactions always occur at anode, reductions reactions always occur at cathode **(Field note)**

Defne was aware of the misconception related to electrolytic cell that was reported by Garnett and Treagust (1992b) as "in the electrolytic cells, oxidation now occurs at the cathode and reduction occurs at the anode". During the stimulated recall interview, she mentioned that she was aware of this possible misconception and she thought students might think that when the half-cell get reversed, the reactions occurring in the half cell also change so she warned them about this **(Stimulated recall interview).** A similar situation was experienced during Zeynep's instruction. While talking about differentiating galvanic cell and electrolytic cell, she pointed out that although the process occurring at galvanic cell and electrolytic cell were reverse, oxidation reaction always occurs at anode and reduction reaction occurs at cathode.

Moreover, regarding electrolytic cell, Zeynep was aware of another misconception reported by the Sanger & Greenbowe (1997a) which is "In electrolytic cells, water is unreactive toward oxidation and reduction". So while she was explaining the electrolysis of aqueous NaCl (sodium chloride), she underlined that H_2O in other words H^+ and OH^- ions should be taken into account during the electrolysis of NaCl (Sodium chloride) solution.

Furthermore, during instruction Defne missed some of the misconceptions that students had. For instance, while explaining the effect of concentration change on cell potential, Defne asked how concentration change effects the cell potential, one of the student stated:

> **Student**: if the concentrations of the electrolytic solutions are different, cell process work and try to equalize concentrations. Otherwise, if the concentrations of the electrolytic solutions are the same, cell does not work.

Although it is true for concentration cell, for galvanic cell it is not true but Defne did not recognize this misconception and passed over this explanation and moved. (Field note)

On the other hand, when pre-service teachers realized the misconceptions, in order to eliminate them, they usually provided the scientifically correct explanation but sometimes they tried to eliminate the misconception utilizing macroscopic representation and demonstration. For instance, while discussing about working principles of galvanic cell and components of galvanic cell as salt bridge, voltmeter and so forth, Defne asked questions to students related to the function of salt bridge and turned back to demonstration in the previous lesson to support her explanation.

> **Defne:** Do you remember previous lesson, what did we observe when we remove the salt bridge from galvanic cell, what happened? [she referred to the galvanic cell demonstration acted in the previous lesson]
> **Students**: after a while, voltmeter indicated zero
> **Defne :** yes, the voltmeter value decrease from 1.05 to 0.00. Okey..what was the reason of it?
> **Student:** when we removed salt bridge, electron transfer stopped.
> **Defne:** Are electrons transfer through salt bridge?
> **Student:** yes, are not they?
> **Defne:** okey then, electrons cannot flow through aqueous solution so they don't travel through the salt bridge, electrons only transfer through the wire [she used the galvanic cell drawing on the PowerPoint].

In Zeynep's class the same event was seen at galvanic cell sub-topic. During the instruction, Zeynep realized the misconception related to flow of electron.

> **Zeynep:** Can you explain which direction electron flow in galvanic cell?
> **Student:** electron flow anode to cathode through the wire.
> **Zeynep:** Then what happens at cathode electrode when electron comes?
> Student: then electron turns back to the anode electrode through salt bridge
> **(Field notes)**

Zeynep explained the flow of electron utilizing the drawing of galvanic cell and half-cell reactions. During the interview, she stated the possible source of this misconception as

"Students have learnt in physics, there is a closed circuit and electron flow around the circuit so electron return the place that starts moving again. Most probably they think it is valid for galvanic cell. By using salt bridge we supply connection between two half-cell so they may think that electron both travel through the wire and salt bridge to complete the circuit"**(Stimulated recall interview)**

In a similar way, Zeynep provided scientifically correct explanation when she elicit misconception during her instruction. While Zeynep was talking about Zn-Cu cell and working principles of this cell such as Zn was anode and Cu was cathode and the reaction occurred at these electrodes using the drawing of the cell (Figure 5), the following excerpt occurred:

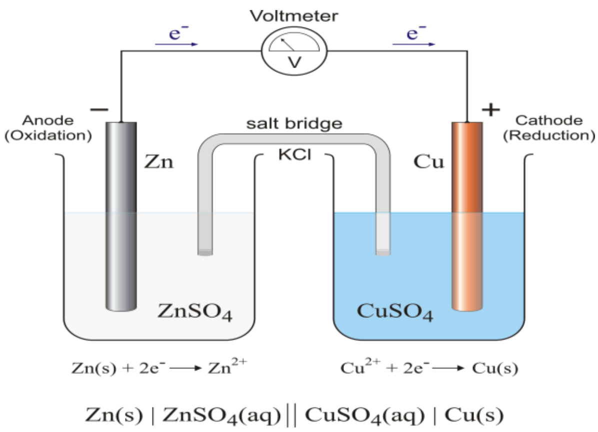


Figure 5. Drawing of galvanic cell presented in Power point

Student: when Zn is oxidized, Zn^{2+} enter the solution so it is liquid.
Zeynep: No it is not, Zn is not melting. Zn ionized so it is in the aqueous phase.

During the interview, Zeynep stated that students may have lack of knowledge regarding phases of matter and, ionization and dissociation.

Based on the observations, another example that although Defne usually provided scientific correct knowledge to students against misconception, she rarely tried to eliminate the misconception using instructional representations such as analogy. An example was observed pertained to standard hydrogen electrode (SHE). Based on her self-experiences as a student and related literature, she was aware of the possible misconception related to SHE that was the reduction potential of hydrogen is zero because of the chemical properties of hydrogen. This misconception was also reported by both Garnett and Treagust (1992b) and Sanger and Greenbowe (1997a). Just after providing the scientific knowledge as hydrogen was chosen as an arbitrary standard potential as a reference point in order to measure the potential of all other electrodes, she enriched her explanation with a sea-level analogy (Field note) During the interview, she stated that

> “I also had this misconception and thought that there should be a reason for choosing hydrogen as a reference electrode and the zero value may be measured with an experiment, so students also may think like me. Starting from this point of view, I emphasized that that is no rule and experiment result related to zero value of hydrogen, it is just a reference point”
> (Stimulated recall interview)

Summary of the results regarding the knowledge of learner components as following see Table 13:

Table 13. Knolwedge of learner for teching electrochemistry

Participants	Sub-components	Purpose of use	The way of using/handling
Defne	**Pre-requisite knowledge**	To link the concepts within the electrochemistry To make the new topic more understandable for students	Teach the new concept using the previous concepts but the connection was superficial
	Difficulties	To eliminate the difficulty that prevent students' understanding the topic	Enriching the scientific explanation by using instructional representations as animations, and algorithmic exercises. Making the abstract nature of topic more concrete using microscopic representations.
	Misconceptions	To eliminate the misconception	Providing scientifically correct explanation
Zeynep	**Pre-requisite knowledge**	To link the concepts within the electrochemistry To make the new topic more understandable for students	Teaching the new concept linking the previous concepts conceptually
	Difficulties	To emphasize the possible difficulty learnt from related literature to help students' understanding	Drawing students' attention by asking questions related to the confusing concept
		To eliminate the difficulty that prevent students' understanding the topic	Enriching the scientific explanation by using instructional representations as animations. Using microscopic and symbolic representation help students to visualize the concepts
	Misconceptions	To eliminate the misconception	Providing scientifically correct explanation

4.3.3 Knowledge of instructional strategy

4.3.3.1 Subject specific instructional strategy

While Defne preferred to use one of the subject specific instructional strategies, Zeynep did not use any of them for teaching electrochemistry. Defne preferred to use 5E learning cycle instructional strategy for electrochemistry instruction in her CoRe. In her CoRe she explained each phase of the engagement, explore, explain, elaboration and evaluation respectively. During the interview, she underlined the appropriateness of electrochemistry to 5E learning cycle as following:

> "I think 5E [learning cycle] is an effective method for students' understanding. Also electrochemistry can be easily adopted to the each stage of 5E. I think this method make students active during the lesson so they can understand meaningfully utilizing 5E learning cycle" **(Stimulated recall interview)**

Another reason for choosing 5E learning cycle is Defne's orientation to science teaching. During the interview, she explained how her goals for teaching science influence her choice of instructional strategy:

> "By using 5E learning cycle, I can reach my goals that determined for teaching chemistry. For instance, in the engagement stage, by using the picture indication frog and cell, I aimed to draw students' attention and increase their interest in chemistry. Also, in the elaboration part, my purpose is to lead them [students] to understand daily life application of electrochemistry and understand what is going on around us" **(CoRe interview)**

However, in her teaching at the high school, she could not adopt 5E learning cycle accurately and effectively to her instruction. Defne guided all the activities and explanations during the instruction, students just participated in instruction actively by answering questions addressed by the pre-service teacher (Defne). After she took students' views on the topics, she provided the scientifically correct explanation to students. Her teaching can be labelled as teacher centered teaching empowered with daily life applications, animation, demonstration, analogy and explicit NOS instruction. For instance, in 5E learning cycle, the first stage is engagement. The main aim of this stage is twofold: to increase learners' interest to the topic with an explorable questions and to revive their prior knowledge regarding the topic. The question used to increase learner's motivation to explore will refer to the exploration stage (Luera, Moyer & Everett, 2005). However, in Defne's instruction, she started the lesson indicating a picture including a frog and a battery and asked students "Is there any link between cell and frog?" Then she moved with the historical development of electrochemistry (Filed notes) so she just aimed to draw students' interest to the topic (Stimulated recall interview)

4.3.3.2 Topic-specific instructional strategy

Topic specific instructional strategies were examined under two sub titles based on Magnusson et al. 1999 PCK model namely activities and representations.

At the beginning of the instruction, both of the pre-service teachers used an interesting picture to draw students' attention. Defne indicated an interesting picture including frog and battery in order to attract students' attention. Then she moved with the historical development of electrochemistry. Congruent with historical development of electrochemistry, she emphasized tentaviness and law& theory aspect of Nature of Science (NOS). The important aspect of her instruction is emphasizing NOS explicitly. She explained why she emphasized this as: "..I want my students learn how electrochemistry develop, how the batteries invented, I mean I emphasize NOS to indicate them how science evolves" **(Stimulated recall interview)**

Zeynep also utilized pictures to draw students' attention in different sub-sections of electrochemistry. She showed a picture including gold plated spoon and car, and asked students' view about the process of plating. She mentioned that: "the purpose of using these pictures, figures is to connect the electrolysis sub topic with daily life applications so the concept will be more concrete for students. The figures included cars, cells that students may come across very usually in their daily life. So I think by using these figures I can lead students to think about how gold plating is done so I draw their attention to the electrolysis topic" **(Stimulated recall interview)** Then similar with Defne, Zeynep moved with the history of electrochemistry and the scientist studying on electrochemistry. Contrary to Defne, Zeynep implicitly emphasized the nature of science during her instruction. She just aimed to arouse curiosity to science, especially chemistry.

Defne and Zeynep utilized algorithmic calculations just after explaining the concept. Defne performed exercises related to standard hydrogen electrode (SHE). SHE, identification of anode, cathode and calculation Ecell value and Nerst equation excluding quantitative calculations of electrolysis. In addition, Zeynep performed calculations regarding quantitative aspects of electrolysis. For instance, Defne explained how concentration change effect cell potential, then she made algorithmic calculations with students on the board regarding Nerst equation and concentration change effect. **(Field notes)** The question that was taken from textbook was as following:

> Consider a galvanic cell that uses that reaction
>
> $Cu_{(s)} + Ag^{+}_{(aq)} (1M) \rightarrow Cu^{+}_{(aq)} + Ag_{(s)}$
>
> Calculate the potential at 25°C for a cell using the standard reduction potential table. Calculate the potential for the following ion concentrations: $[Ag^{+}] = 0.1M$ and $[Cu^{+}] = 0.01M$

Zeynep provided knowledge regarding electrolysis of water and indicated a video related to it, then she performed an exercise with the students on the board. The question was as following:

> At standard conditions, electrolysis of water gives 5.6 L gases at cathode electrode. Using the standard reduction potential table,
>
> a) Predict the half-cell reactions that occur at anode and cathode.
> b) Find how many liters of gases produce at anode.
> c) Calculate the current required for this electrolysis of water process.

4.3.3.2.1 Activities

Zeynep and Defne performed two demonstrations during their instructions. While one of them was regarding spontaneity of redox reactions, the other one was related to galvanic cell. Although both of the participant used same demonstrations, the sequence of the demonstrations were different. Defne performed one of the demonstration to investigate whether each redox reaction occur spontaneously at the beginning of the topic. A zinc metal was immersed in copper sulfate solution, while a copper metal was immersed in zinc sulfate solution. Defne employed the demonstration and students observe the redox reaction occurring only between Zn (zinc) and $CuSO_4$ solution. When asked the reason of using this demonstration she explained: "…to catch students' attention..I think demonstrations make the content more concrete and catchy..also by using this demonstration spontaneous and nonspontaneous concepts can be more understandable" (**Stimulated recall interview**)

Zeynep also followed the same process but there were some alterations. Firstly, in addition to draw attention of students, Zeynep stated the aim of using this demonstration was as "...just before moving the standard reduction potential sub-topic, I would like to lead students understand spontaneity concept and reactivity of metals so by this way they easily understand how standard reduction potential table was formed" (**Stimulated recall interview**). The second one is Zeynep prepared a handout including purpose, process that students should follow and space for their observations. During the demonstration, she discussed why redox reactions occurred between Zn (zinc) and $CuSO_4$ solution or why no reaction occurred between Cu and $ZnSO_4$ solution in terms of reactivity of metals.

The second demonstration was related to galvanic cell (Zn–Cu cell) and performed while explaining the galvanic cells and working principles of that. Both of the pre-service teachers distributed a handout to guide students to pursue the demonstration. The purpose of this demonstration was make the content concrete for students. Zeynep stated that "Every single student has different learning style so enriching the conceptual knowledge with this kind of demonstration may improve students' understanding" (**Stimulated recall interview**) In addition, both of them aimed to elicit students' possible misconceptions by using demonstration. For instance, Defne explained the function of salt bridge by indicating through the demonstration so she believed by this way she helped students understand the content easily (**Stimulated recall interview**). Also, Zeynep explained the components of galvanic cell and asked students "what will happen if we remove the salt bridge from the system? Or why did we read zero when we removed the salt bridge from the system?" (**Field notes**)

Although Defne did not use any activities besides her conceptual explanations regarding electrolytic cell, Zeynep showed videos to enrich her instruction during the electrolytic cells. She showed videos regarding electrolysis of water and NaCl solution, and electroplating process. She mentioned her purpose of using these videos as "I would like to support the information provided about electrolysis with visual materials. In order to learn meaningfully, I tried to provide daily life applications of the topic and attract students' attention to the topic"

4.3.3.2.2 Representations

Beside demonstrations, pre-service teachers used three representations of chemistry namely symbolic, macroscopic and microscopic level. Defne used three representations together for teaching galvanic cell but she overlooked using these representation for teaching concentration and electrolytic cell. She generally provided macroscopic drawing of a cell and symbolic representations of reactions as shorthand notations for sub-topics of electrochemical cells. She underlined the importance of using these representations as:

> "As I know from my own experiences, visual images are more prone to stick in mind so I explained the same concept both drawing the cell on the board and providing explanation about it. Student may forget what I said but they can understand more easily when they see" **(Stimulated recall interview).**

Macroscopic drawings taken from Defne's PowerPoint slides were following: (See Figure 6 and Figure 7)

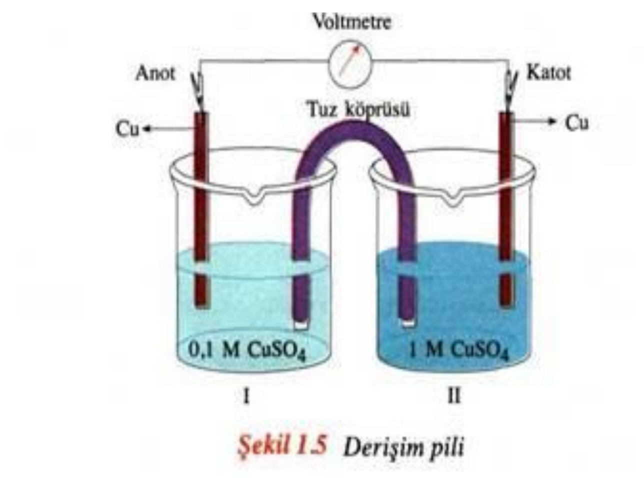


Figure 6. Drawing of concentration cell

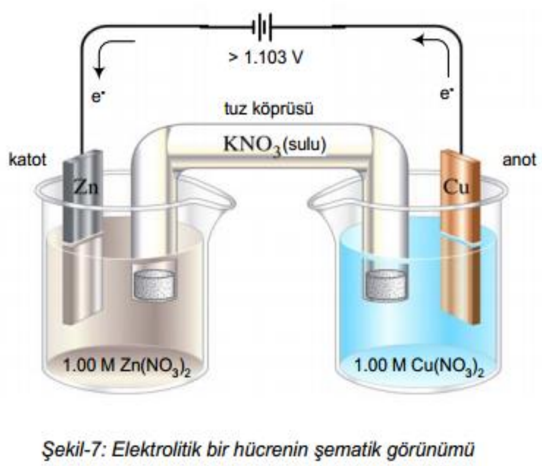


Figure 7. Drawing of electrolytic cell

Defne used microscopic representations during the animation while teaching galvanic cells (Field notes). During stimulated recall interview, she underlined the importance of using microscopic representation in terms of making the abstract nature of the topic more concrete and leading learners to visualize what is going on in the batteries. Furthermore, Defne stated that

> "…the lack of knowledge of students pertained to atomic level prevented them to understand meaningfully so by using animations including microscopic level help students to understand the working principles of cells and what is going

> on each half cell..maybe we can prevent students from possessing possible misconceptions by this way..”**(Stimulated recall interview)**

On the other hand, Zeynep used three representations for teaching galvanic and electrolytic cell. Symbolic representations and macroscopic drawings of cells were always provided to students as similar with Defne’s instruction. However, Zeynep used microscopic representation utilizing animation while providing knowledge in only galvanic and electrolytic cells. During the interview, she stated the importance of using different representation as:

> “the importance of using multiple representations is make concrete the abstract concept and more understandable…otherwise, just presenting the content is not effective without using demonstration or using animation including microscopic level. For instance, regarding activity [demonstration related to reactivity of metal], just saying active metal loses electron more readily than passive metal to form positive ions not so effective merely or for the other demonstration [galvanic cell demonstration] while explaining it was said the anode loses mass, the cathode gains mass but how this will happen, why one of the electrode will decrease and the other will increase in mass. By making a demonstration, we could not observe it so animation support the demonstration via microscopic level so students can understand meaningfully” **(Stimulated recall interview)**

Furthermore, Defne and Zeynep implemented analogies during her instruction. For instance, Defne used a sea level analogy while explaining Standard hydrogen electrode (SHE). SHE is used as a reference half-cell. She mentioned:

> “As you remember while measuring a mountain we accept the sea level zero although there is an area above sea level. As a sea level, we accept SHE as a reference point and measure the other reduction potentials according to it” **(Field notes).**

The underlying reason of Defne’s analogy usage is: “…I link the SHE with the concept [sea level] they are similar. I both attract their notice and..I think by this way they can learned easily”.

Another analogy also used by both Zeynep and Defne that was waterfall analogy while explaining spontaneous and nonspontaneous reactions. Zeynep articulated that: “In the height of the waterfall, the potential energy is high and spontaneously move to the bottom of the waterfall. But for a reverse situation, we have need external power and occur nonspontaneous" **(Field notes).** However, while using the analogy, she did not emphasize the differences and similarities of analogy and spontaneity concept.

During the instructions, both Zeynep and Defne made comparison between galvanic cell and electrolytic cell at the beginning of the galvanic cell sub topic but they present the knowledge in different way (see Table 14). Defne used comparison table in power point slides, but she just read the explanations in the PowerPoint. In her verbal explanation, she didn't emphasize the difference in terms of spontaneity, energy and charge of the electrodes. During stimulated recall interview, she explained why she used this comparison table:

> "When I was student, I couldn't discriminate electrochemical cell and electrolytic cell concepts so I tried to prevent my students from misunderstanding. I wanted to explain the topic more organized way in other word from the general to the specific"

Table 14. Comparing galvanic cell and electrolytic cell

ELECTROCHEMICAL CELLS	
Galvanic cell	**Electrolytic cell**
Systems that convert chemical energy into electrical energy.	Systems that convert electrical energy into chemical energy with the help of external power.

On the other hand, Zeynep preferred to use drawing of galvanic and electrolytic cell to compare these cells. She explained the differences of these cell both verbally and visually and pointed out that while galvanic cell has a positive cell potential ($E^o_{cell} > 0$), Electrolytic cell has a negative cell potential ($E^o_{cell} < 0$) (Field notes)

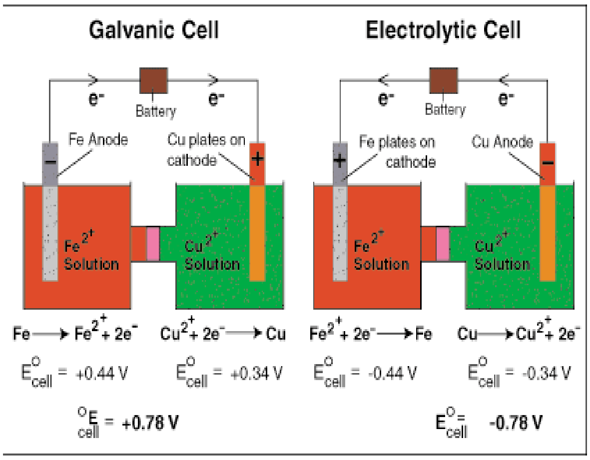


Figure 8. Representation of galvanic and electrolytic cell

Eventually, both of the pre-service teachers mentioned daily life applications of electrochemistry. At the end of the lesson, they mentioned battery types that we came across in our daily life namely dry cell batteries (Zn-MnO_2), lead storage battery, Nikel-Cadmium (Ni-Cd) batteries and Lithium batteries. They provided general explanations and pictures regarding battery types by using PowerPoint slides. Furthermore, Zeynep mentioned the commercial applications of electrolysis using videos and animations. She indicated videos and provided explanations pertained to how electroplating is used and electrolysis of water and NaCl solution **(Field note).**

In the interview, Defne explained why she emphasized the daily life usage to electrochemistry as:

> "I tried to apply 5E learning cycle in my instruction so at the elaboration part I mentioned the daily life applications of the topic[electrochemistry]…by this way, students become aware of how the battery work and link battery to the electrochemistry…We use electrochemistry in every part of our life for instance in our laptops, cell phones,Mp3 players..when student go to buy battery, they can use their knowledge about electrochemistry"**(Stimulated recall interview)**

Similar points were also emphasized by Zeynep as:

> "From my own experiences as a student, when you learn the logic behind the theoretical knowledge and usage of it in our life, this makes the knowledge

> permanent. The aim of my instruction is make students understand what is happening around us and developmental process of technology so this prepare the students as scientifically literate citizens….also they gain a general knowledge...by emphasizing daily life application of the topic, students focused on the instruction so maybe it can increase their attitude to science" **(Stimulated recall interview)**

Table 15 indicated the summary of the results pertained to knowledge of instructional strategies component:

Table 15. Knowledge of instrcutional strategy for teaching electrochemistry

			Defne		Zeynep	
Sub components			**The way of using**	**Purpose of using**	**The way of using**	**Purpose of using**
Subject specific instructional strategy	5E learning cycle		Tried to apply all stages of 5E learning cycle during the instruction but not so effective.	To reach the goals determined for teaching science To make students active and improve their understanding on the topic	----	-------
Topic specific strategy	Representations		Using three representations of chemistry (symbolic, macroscopic and microscopic) on galvanic cell Using animations regarding galvanic cell Using analogies (seal-level and water fall)	To make the content more concrete and help learners to visualize what is going on.	Using three representations of chemistry (symbolic, macroscopic and microscopic) on galvanic cell and electrolytic cell Using animations regarding galvanic and electrolytic cell Using analogy (waterfall)	To make the abstract content more concrete and understandable
	Activities	Demonstration	Using demonstration regarding spontaneity of redox reactions and galvanic cell	To attract learners' attention To make the content more concrete and understandable for students To eliminate leaners' possible misconceptions	Using demonstration regarding spontaneity of redox reactions and galvanic cell	To attract learners' attention To make the content more concrete and understandable for students
		Videos	----	-----	Using videos regarding electrolysis of water and NaCl solution, and electroplating.	To provide the conceptual explanations with visual materials To attract learners' attention

Table 15 (continued)

	Defne		**Zeynep**	
	The way of using	**Purpose of using**	**The way of using**	**Purpose of using**
Daily life usage of Electrochemistry	Explaining the common battery types used in daily life	To relate the topic to the daily life	Explaining the common battery types used in daily life Explaining the commercial use of electrolysis as electroplating	To relate the topic to the daily life To increase learners' positive attitude to science
Algorithmic Calculations	Performing exercises on galvanic cell and on Nerst equation	To make learners to practice what they learnt	Performing exercises for each sub-topic	To make learners to practice what they learnt
NOS (Nature of Science)	Emphasized tentaviness and theory & law aspect of NOS explicitly Explained historical development of electrochemistry	To lead learners to develop positive attitudes towards science	Explained historical development of electrochemistry	To arouse curiosity towards science

4.3.4 Knowledge of curriculum

4.3.4.1 Knowledge of goals and objectives

Defne and Zeynep can be accepted as partially knowledgeable about goals and objectives of electrochemistry topic. While preparing their CoRe, they wrote objectives that they addressed during their instruction. Most of these objectives were chosen utilizing the national high school chemistry curriculum. In addition to objectives presented in the national chemistry curriculum, they also added alternative objectives while preparing her CoRe and mentioned these objectives during the interview. For instance Defne wrote:

> "Students should be able to understand the nature of science by explaining history of battery and students should be able to design galvanic cell experiment" **(CoRe)**

National high school chemistry curriculum included objectives, limitations and warning related to topic, possible misconceptions that teacher should consider and suggestions regarding activities that can be utilized during instruction. Defne and Zeynep were aware of most of the objectives stated in the curriculum, however they were not conscious about the limitations and cautions related to the topic. For instance, during the instruction both of the pre-service teachers gave examples regarding batteries used in daily life parallel with the objectives stated in the curriculum as:

> Students should be able to give examples regarding common batteries.
> (NME, Objective 3.2, p. 65)
> Students should be able to explain the working principles of rechargeable batteries common examples as lead storage battery. (NME, Objective 3.3, p. 65)

However, they didn’t take in consideration warnings mentioned in the curriculum as:

“It is suggested to give chemical reactions occurring in the batteries” (NME, Warning,3.3, p.65)

During the instructions, they covered all the objectives determined in the CoRe. For instance, there was an objective as following

> Students should be able to give examples of industrial applications of electrolysis (objective 3.5, p. 65, NME 2012)

During the instruction just after electrolysis sub topic, they provided examples pertained to commercial applications of chemistry namely purification and electroplating of metals. For instance, Defne provided just some explanation about the process of electroplating of metals and the importance of this process in our life. She mentioned that “For instance, iron will rust and iron rusting is indication of corrosion. We can plate the surface of the iron with another metal that resistant to corrosion to protect them corrosion.” **(Filed note**)

Zeynep also used videos to empower her explanation related to industrial applications of electrolysis and indicated video pertained to how electroplating process works especially electroplating a key with copper **(Field notes).**

4.3.4.2 Curricular Saliency

One of the indication of understanding curricular saliency is knowing the topic that come before and after electrochemistry. During the interview, when it was asked the place of the topic in the curriculum and which topics are taught before and after electrochemistry, both of the pre-service teachers stated that before electrochemistry chemical equilibrium should be taught and after the electrochemistry, nuclear chemistry should be taught.

Moreover they also had a sound understanding regarding the sequence of sub topics in the electrochemistry. For instance, Defne considered the importance of understanding the main concepts within the electrochemistry topic such as learning anode, cathode, oxidation and reduction reactions in order to understand working principles of galvanic cell. Another example that can be indicator of Defne's knowledge of curricular saliency was as following:

> "Firstly students should learn spontaneous and nonspontaneous reactions. If they don't know what these reactions mean exactly, they have difficulty in differentiating galvanic and electrolytic cells. So first I emphasize spontaneous and nonspontaneous reaction and highlight that in galvanic cell spontaneous redox reactions occur, in electrolytic cell nonspontaneous redox reactions occur" **(CoRe interview)**

Zeynep was also aware of the sequence of sub-topics as presented in the national high school chemistry textbook. She stated that the sequence of the topics as:

> "Firstly redox reactions and activity, then historical development of cell from Galvani to Daniel, then galvanic cell and standard electrode potential, then factors affecting cell potential, working principles of galvanic cells, common batteries used in daily life then electrolytic cell and application in daily life" **(CoRe interview).**

A specific example may be found in the CoRe. Zeynep wrote that: "Students will understand what factors that electrode potential depends and they can find electrode potentials mathematically by using Nerst equation" **(CoRe)**

4.3.4.3 Altering the curriculum

When Defne's instruction and her CoRe were taken into account, she did not have adequate knowledge to alter the sequence of subtopics in electrochemistry. She strictly pursued the high school chemistry textbook and accepted the textbook as a guide. She just decided to teach redox reactions, galvanic cell, concentration cell and electrolytic cell respectively after then she taught the batteries and commercial applications of electrolysis different from the topic sequence stated in the curriculum. During the interview she explained the reason of this change as:

> "During my instruction I used 5E learning cycle as instructional method. I preferred to teach daily life applications of the topic after I explained all the main concepts in parallel with my instructional strategy in the elaboration step of 5E learning cycle". **(Interview)**

Similar to Defne, Zeynep didn't alter the sequence of the sub-topic in electrochemistry. She pursued the sequence of the topic presented at the high school chemistry textbook. She explained the reason of this as " I don't have so much experience in teaching so I don't want to take risk and follow the high school chemistry textbook" **(Stimulated recall interview)**

4.3.4.4 Vertical curriculum

Based on the analysis of related data and observations, Defne did not make any link between electrochemistry and topics that students learned previous years or topics that student are expected to learn in later years. On the other hand, Zeynep referred the 9th Grade and stated that "..at the 9th grade you are supposed to learn reactions types and redox reactions is one of them. Do you remember?" **(Field notes).** She aimed to remind the topic they have learned previous years and make students aware of regarding the topic in chemistry are related.

4.3.4.5 Horizontal curriculum

Both participants connect electrochemistry to the previous topics in the 11th grade especially chemical equilibrium topic. According to the analysis that was done to identify relation Defne made between electrochemistry and previous and next topics in the 11th Grade, it was detected that she only made relation to previous topics namely chemical equilibrium and entropy. For instance, during explaining the working principles of galvanic cell, she connected the topic especially the flow of ions through salt bridge with chemical equilibrium. During the instruction, this explanation was observed:

> "….in the anode half-cell, the positive ions will increase so the anions flow through salt bridge to the anode compartment. In the previous topics you learnt chemical equilibrium, you can interpret the flow of ions through salt bridge

> utilizing chemical equilibrium in order to maintain neutrality.”**(Video recordings).**

It can be interpreted that she just mentioned the previous topic but she could not make conceptual relation between topics so her knowledge of horizontal curriculum was superficial.

Similarly, during the factors affecting cell potential of galvanic cell, she linked the topic with Le Chatelier’s principle in chemical equilibrium. During the instruction Defne wrote a chemical equilibrium reaction as:

$$aA_{(s)} + bB^{+}_{(aq)} \rightleftarrows aA^{+}_{(aq)} + bB_{(s)}$$

and Defne said “..you heard about the Le Chatelier’s principle, right ..what does this principle mean?”

Defne and students together summarized what Le Chatelier principle stated and talked about the effect of concentration changes on the equilibrium. Then Defne directly moved to the Nerst equation **(Field notes).** As it can be seen, Defne just mentioned the related topic but she could not link these topics conceptually for instance she did not mention how students can utilize Le Chatelier’s principle to predict effect of concentration change on cell potential. On the other hand, Zeynep linked electrochemistry and chemical equilibrium conceptually. Zeynep also wrote a chemical reaction as Defne wrote, and with students she wrote the equilibrium constant as $K= [A^{2+}]/ [B^{2+}]$. Then they talked about the effect of concentration changes on cell potential. She mentioned that if we increased the reactant ion concentration, cell potential will increase.

During the interview, the reason for utilizing horizontal curriculum was asked, Defne mentioned:“…by making relation, I draw their [learners] attention to the topic [chemical equilibrium] that you have already learnt then students can combine the new knowledge with chemical equilibrium so they learn the new topic [electrochemistry] more easily” **(Stimulated recall interview)**

Also Zeynep articulated similar reason regarding associated the topics. She stated that:

> "In electrochemical cells, there are chemical equilibrium reactions. I refer chemical equilibrium topic in order to help students link between the topic they have learnt and the new topic so they can understand the new topic easily. Also I want to lead students to think that all chemistry topics are dependent each other"

4.3.4.6 Connection to Other Disciplines

Zeynep connected electrochemistry to physics topics that students have already learnt. For instance, during the algorithmic calculations regarding the faraday's law in electrolytic cell sub-topic, she referred to the physics. During the interview, she explained the importance of linking disciplines as:

> **Zeynep:** Students should be able to understand there is a link between physics and chemistry, there are not completely separated. In order to explain a concept in science, we utilize different scientific disciplines. Moreover, while explaining the new topic, refer to another topic they have already learnt make easier to understand the new topic. Also, this is important to understand the nature of science.
> **Researcher:** How connecting the scientific disciplines lead them to understand NOS?
> **Zeynep:** Creativity is the starting point for scientific research and to proceed the scientific research, scientists work in collaboration. For instance, in order to explain the same concept, physicists and chemists consider it from different perspectives. **(Stimulated recall interview)**

Defne didn't associate electrochemistry with physics topics explicitly during her instruction.

Table 16 indicated the summary of the ways of using knowledge of curriculum for both pre-service chemistry teachers.

Table 16. Knowledge of curriculum for teaching electrochemistry

Zeynep	Sub-components	Purpose of use	The way of using
	Vertical curriculum	To remind the topic they have learnt and help them relate the new topic (electrochemistry) to the previous topic (reactions types)	Asking questions that help learners to remind the previous topic and get the relation
	Horizontal curriculum	To help students link between the topic (chemical equilibrium) they have learnt and the new topic (electrochemistry) so they can understand the new topic easily To lead learners to think that chemistry is a whole and the topics are related.	Explain the concept in the new topic utilizing the knowledge provided in the previous topics and linked the concepts conceptually.
	Connection to other disciplines	To help learners remember the knowledge learned in physics to explain the new topic	Referring the concepts in physics to help learners to associate the concepts from different science disciplines
	Curricular saliency	Giving the sub-topics in a sequence help students to understand in a meaningful way	Knowing the sequence of the topics and the sub-topics presented in the national curriculum and give the concepts in a sequence similar to curriculum.
	Altering the curriculum	------	------
	Knowledge of goals and objectives	Using the objectives presented in the national curriculum and add additional objectives regarding daily life.	Being aware of the objectives presented in the national curriculum but don't be conscious about warnings and limitations.

Table 16 (continued)

Defne	**Sub-components**	**Purpose of use**	**The way of using**
	Vertical curriculum	-----	-------
	Horizontal curriculum	To draw attention to the topic learners already learnt and link the new topic with the previous topic(chemical equilibrium) so make learning the new topic easier	Just mentioned the previous topic but she *could not make conceptual relation between topics*
	Connection to other disciplines	------	-------
	Curricular saliency	Giving the sub-topics in a sequence help students to understand in a meaningful way	Knowing the sequence of the topics and the sub-topics presented in the national curriculum and give the concepts in a sequence similar to curriculum.
	Altering the curriculum	-----	-------
	Knowledge on goals and objectives	Using the objectives presented in the national curriculum an add additional objectives regarding NOS and daily life	Being aware of the objectives presented in the national curriculum but don’t be conscious about warnings and limitations.

4.3.5 Knowledge of assessment

In this part the results provided pertained to pre-service teachers' using knowledge of assessment and the Table 17 indicated the summary of the results.

Table 17. Knowledge of assessment for teaching electrochemistry

Methods of Assessment(how to assess)	**Types of Assessment**	**Why to assess**	**Types of questions**	**When to assess**	**Dimensions of science learning to assess (what to assess)**
Informal Questioning	Diagnostic	To identify students' prior knowledge or misconceptions	Open-ended questions	During the lesson	Prior knowledge and possible misconceptions
	Formative assessment	To identify student's understanding about the topic	Open-ended questions	During the lesson	Conceptual understanding, NOS understanding , Daily life applications
Homework	Summative assessment	To identify students still have misconceptions or not	True/False and open-ended question	At the end of the topic	Conceptual understanding

4.3.5.1 Knowledge of methods of assessment (how to assess)

During the electrochemistry instructions, both of the pre-service teachers used only two assessment methods namely, informal questioning and homework. They utilized informal questioning method during their instruction for two purposes: to recognize prior knowledge or possible misconceptions and to identify students' understanding about the topic. On the other hand, they used homework at the end of the topic to assess students' understanding and check if there was any scientifically incorrect knowledge at the end of the instruction. However, pre-service teachers differentiated in content of the homework. While Zeynep preferred to use interesting questions that students need to search to respond in the homework, Defne preferred to use open-ended questions that focused on content knowledge in the homework.

Both Defne and Zeynep preferred to use informal questioning method as formative assessment in her CoRe and also they used this method for formative and diagnostic assessment. During the interview Defne explained the underlying reason of her choice as:

> **R:** In your CoRe you wrote that you are going to use informal questioning for formative assessment. Similarly, you used this method during your instruction. Why did you prefer to use informal questioning?
> **Defne :** …during instruction I ask questions by this way I can keep students active..This is effective..when I asked question to whole class, each student think about the question and try to find the answer so I lead them to think about the topic."**(Stimulated recall interview)**

For the same question, Zeynep mentioned that "I used formative assessment during my instruction, for instance while making a galvanic cell experiment or after explaining the concepts. By using formative assessment, I aimed to assess if students gained the knowledge meaningfully or not" **(Interview)**

At the beginning of the instruction, as diagnostic assessment both pre-service teachers asked open-ended questions to identify students' prior knowledge. For instance, Defne asked questions to bring to light the prior knowledge of students regarding electrochemistry such as "What is electrochemistry" and "Do you know why cell have a definite time?"

Moreover, during the electrochemistry instruction several examples were observed related to informal questioning usage to recognize possible misconceptions of students. Both of the pre-service teachers used demonstrations of galvanic cell with whole class, then asked questions related to the components of the galvanic cell (Field notes). For instance, Defne asked 'why did galvanic cell stop when we removed salt bridge?". During the stimulated recall interview, she explained the purpose this question to elicit the possible misconceptions regarding the function of salt bridge. She was aware of the students' possible misconceptions related to salt bridge. Similar situation was observed during Zeynep's instruction, she also asked questions regarding working principles of galvanic cell as "How do electrons flow in a galvanic cell?" in order to elicit if students have scientifically incorrect knowledge regarding the topic.

In order to assess students' understanding both Zeynep and Defne used formative assessment throughout the topic. Defne preferred to use informal questioning but the level of questions were generally knowledge level questions and she had difficulty in interpreting the feedback taken from students in order to change her instructional decisions or reteach the missing point for students. For instance, after explaining how the standard reduction table was used to determine anode and cathode in electrochemical cell, pre-service teacher and student performed the question on the board together and she gave feedback when necessary but she had difficulty in interpreting the information she got from the assessment (Field notes). On the other hand, Zeynep used laboratory activity sheet related to galvanic cell demonstration and aimed to assess students' understanding via the questions presented on the sheet as following:

1) Which department belongs to anode and which one is cathode?
2) If salt bridge removed from the system, what will be happened?
3) Does the system produce electricity forever?
4) In order to reverse the reaction that takes place in the cells, what could be done?

Also Zeynep used conceptual questions to assess students' understanding, she had difficulty in utilizing the feedback taken from students to reteach the problematic parts for students in the topic. For instance, she asked students if the system produce electricity forever and students responded the question as: "electrode will finish, the electrolytic solution will evaporate so forth" **(Field notes).** Although students responded to the question, Zeynep didn't take into account the answers and just explained the scientifically correct explanation as "system will stop when it reaches the equilibrium". During the interview, she explained the reason of this due to lack of teaching experience and classroom management skills.

At the end of the instruction, as summative assessment, Defne prepared a worksheet that including open-ended questions and true/false questions and gave this worksheet to students as a homework at the end of her instructions in order to identify if students still have misconceptions related to topic and how much they learn. The example items were below:

> C. Read each statement below carefully. Mark T if you think a statement it TRUE. If you think the statement is FALSE please mark F and write correct explanations in the box.

The standard electrode potential for hydrogen electrode is zero due to the chemical property of hydrogen.	(T) (F)	
In concentration cells, the spontaneous reaction is through the more concentrated solution.	(T) (F)	

Zeynep also used homework at the end of the instruction, but she preferred to use a question researchable. At the end of the lesson, she asked to whole class to search "How was man-made diamond produced?"

During the interview she stated that

> "my purpose of choosing such a question was to lead students to learn how to search scientific knowledge and try to link this knowledge to the topic that they learnt. Also by this way I could attract their notice and maybe they gain a perspective on scientific issues".

4.3.5.2 Knowledge of dimensions of science learning to assess (What to assess)

Both of the participants assessed mainly content knowledge but they did not ignore to assess Nature of Science (NOS) and daily life applications of electrochemistry utilizing diagnostic, formative and summative assessment methods during their instructions.

Defne tried to assess NOS understandings of students to identify their prior knowledge related to NOS aspects especially tentativeness and theory& law via informal questioning during the instruction. For instance, at the beginning of the instruction she asked “What is theory? What is law? Is there any hierarchy between law and theory?” In addition to NOS, Defne assessed students’ knowledge pertained to relation between daily life and electrochemistry via informal questioning. She asked students that “Does cell have a definite time or does a cell work forever?” **(Field notes).** Contrary to Defne, Zeynep emphasized NOS implicitly and just asked students’ imagination about the scientist.

While Defne used open-ended questions and true-false questions to assess the content regarding galvanic cell, Zeynep only used open-ended questions to assess the content related to both galvanic and concentration cell during their instructions. For instance, both of pre-service teachers’ open ended questions were related to galvanic cell and its working principles. Learners are supposed to answer questions utilizing their information related to balancing the redox reaction, deciding which electrode anode or cathode by using standard reduction potentials, the direction of electron flow and how mass of electrode changes, and shorthand notation of cell. The example of the question pertained to galvanic cell as shown Figure 9.

Zeynep also used open ended questions to assess students’ understanding related to concentration cell. The items of the question included deciding anode and cathode and required writing the reactions occurring at anode and cathode, and calculating the cell potential using Nerst equation. Also the changes occurring in the both half-cells were asked. An example of the question was provided in Figure 9 and Figure 10.

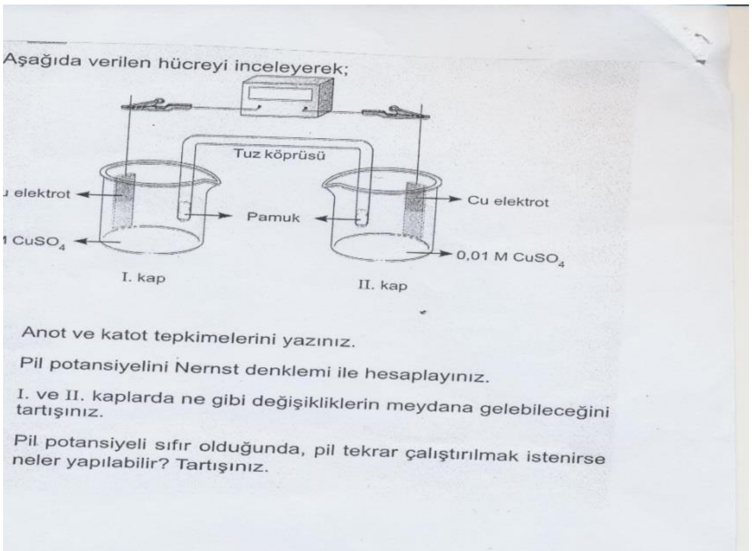
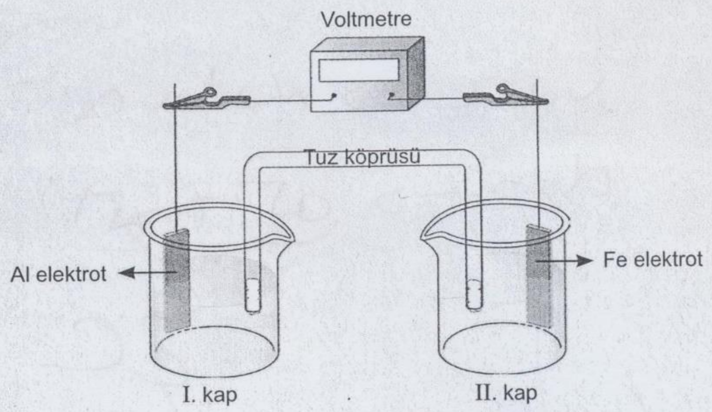


Figure 9. A question example from Zeynep's

Öğrendiklerimizi Uygulayalım



1 M $Al_2(SO_4)_3$ çözeltisi　　1 M $Fe_2(SO_4)_3$ çözeltisi

Al ve Fe'in standart indirgenme potansiyelleri;

$Al^{3+}_{(suda)} + 3e^- \longrightarrow Al_{(k)}$　　$E^0 = -1,66$ V

$Fe^{3+}_{(suda)} + e^- \longrightarrow Fe^{2+}_{(suda)}$　　$E^0 = +0,77$ V

Yukarıdaki şekilde verilen elektrokimyasal hücre için aşağıdaki soruları cevaplayınız.

a) Yükseltgenme-indirgenme yarı reaksiyonları ve toplam pil tepkimesini yazarak standart pil potansiyelini bulunuz.

b) Hangi elektrodun anot, hangi elektrodun katot olduğunu belirleyiniz.

c) Hangi elektrodun kütlesi azalır? Belirleyiniz.

ç) Hangi elektrot dış devreden elektron alır?

d) Hangi kaptaki negatif iyon konsantrasyonu artar?

e) Hangi kaba tuz köprüsünden negatif iyonlar gelir?

f) Pil şemasını yazınız.

Figure 10. An example from Defne 's questions

4.4 Pedagogical Content Knowledge and Content Knowledge Interaction

4.4.1 Content knowledge and Science teaching orientation interaction

Content knowledge influenced science teaching orientation of pre-service teacher regarding determining the active role of teacher during the instruction. For Defne's case, in galvanic cell, she constructed her instruction involving demonstration, analogy and animation so she tried to involve students in class and keep them active in instruction also she created class environment that gives a chance for discussion. However, in sub topics that she had less content knowledge namely concentration and electrolytic cell, she tended to talk more and student had a passive role. For Zeynep's case, similar to Defne, she enriched her instruction with discussion, demonstration, animation, analogy and videos to keep student active during her instruction. During the interview, she explained the role of her content knowledge on her role of a teacher:

> "I know the basic concepts of electrochemistry but in addition to this I know the nature of topic, history and daily life applications of electrochemistry so I choose discussion method and try to participate the students actively into the instruction" **(Interview)**

4.4.2 Content knowledge and Knowledge of learner interaction

Defne reflected her opinion about the link between her content knowledge and knowledge of students' understanding regarding electrochemistry topic as the following interview quotation indicate:

> "My content knowledge influence my knowledge regarding students' understanding [knowledge of learner] so much…I mean while I was learning electrochemistry, I had difficulty in understanding some parts of the topic so I am more aware of the possible difficulties that students may have...while I am explaining the concept in the class, I emphasize the concept that I find hard to understand especially because I think on misconceptions we [students and she] are at one with each other. If I were not aware of these misconceptions, I would not mention them" **(Interview)**

Defne and Zeynep possessed partial knowledge regarding students' misconceptions and difficulties about electrochemistry through reading the related literature and self-experiences. They differentiated in one point as while Zeynep was aware of the misconception and difficulties related to the all sub-topics of electrochemistry, Defne was mainly aware of misconceptions and difficulties regarding galvanic cell in parallel with their content knowledge.

When it was observed during the instructions Defne generally emphasized the misconceptions that she had as a student in previous. For instance, she stated that she had thought that "...Salt bridge seems like a bridge between two half-cell so in order to complete the circuit electron moves through salt bridge so I think there may be some students think like me"(**Stimulated recall interview**). She utilized her lack of knowledge to understand better the concepts that students find difficult to grasp in electrochemistry and the possible reasons of this difficulty. In other words, challenging point in her content knowledge influenced her PCK in terms of knowledge of learner. On the other hand, Zeynep was also aware of the misconceptions but she didn't emphasize the misconceptions during her instruction as Defne. For instance, although she knew that standard hydrogen electrode was chosen arbitrarily and the zero value of E^0 is not due to its any chemical properties as a content knowledge, during the instruction she overlooked that students might have difficulty in understanding standard hydrogen electrode **(Field note).** During the interview, she stated that "I generally know the possible misconceptions and difficulties from articles but in real classroom environment I sometimes could not recognize this misconception due to lack of teaching experience" so having adequate content knowledge on a topic doesn't guarantee to utilize this to identify students' understanding.

Compared to Zeynep, Defne did not have robust content knowledge in electrochemistry so she made an effort to increase her content knowledge while teaching electrochemistry. When we examined in terms of sub topics, she was more knowledgeable in galvanic cell by comparison with electrolytic cell and concentration cell. Although for galvanic cell, she was aware of most of the possible misconceptions and difficulties and she emphasized them during her instruction by making scientific explanations, she ignored the misconceptions regarding concentration cell and for the electrolytic cell. For these sub-topics, only one example was observed.

Corresponding to students' views including misconceptions related to topic, Defne made correct explanations rather than probing the underlying reasons of students' ideas. In other words, her explanations could not move beyond superficial explanations. She tried to eliminate misconceptions rarely using instructional strategies as animation or analogy. For instance, she stated that in the past, she had thought that standard hydrogen reduction potential value is zero due to its chemical properties so she need to emphasize that standard hydrogen electrode was randomly selected and just a reference point during the instruction. In addition to scientific explanation, she utilized analogy to make this more understandable for students. But sometimes she missed the misconceptions and difficulties students might have. For instance, while explaining galvanic cell, she asked students the direction of electron flow in galvanic cell, and one student answered as "from positive charge to negative charge" then Defne corrected student answer as from anode to cathode **(Field note).** After instruction, when it was asked Defne's view on the student's answer in interview, she stated that she could not understand why students said like this and she moved on the other topic. In physics course, students learnt that electric current flow from positive charge to negative charge. Also the direction of electric current and electron flow are reverse. In chemistry, electron flows from anode, negative charge, to cathode, positive charge. Due to the lack of knowledge of Defne in terms of determining the charge of electrodes and the link between physic and chemistry, she could not diagnose the difficulty students have in understanding the direction of electron flow. Table 18 indicated the summary of results regarding the interaction between knowledge of learner and content knowledge for teaching electrochemistry for both pre-service chemistry teachers.

Table 18. The interaction between knowledge of learner and content knowledge teaching electrochemistry

	Defne's KoL		**Zeynep's KoL**	
	Prerequisite knowledge	**Misconceptions and difficulties**	**Prerequisite knowledge**	**Misconceptions and difficulties**
Content knowledge	Defne knows the prerequisite knowledge to make links within electrochemistry and links between electrochemistry and other topics.	Defne was mainly aware of misconceptions and difficulties regarding galvanic cell in parallel with their content knowledge. She ignored the misconceptions regarding electrolytic cell and concentration cell due to lack of knowledge in these topics. Defne emphasized the misconceptions explicitly that she had as a student in previous during instruction.	Zeynep knows the prerequisite knowledge to make links within electrochemistry and links between electrochemistry and other topics.	Zeynep was aware of the misconception and difficulties related to the all sub-topics of electrochemistry. Zeynep sometimes did not emphasize misconceptions although she knew the content and aware of the misconception during instruction.

4.4.3 Content Knowledge and Knowledge of instructional strategies interaction

4.4.3.1 Content knowledge and Subject specific strategies interaction

During the instruction, Defne chose 5E learning cycle instructional method. During the interview, she explained the underlying reason of 5E learning cycle method selection as:

> **R:** How did you decide your teaching method?
> **Defne:** sure..I know the content of the topic [electrochemistry] so I said 5E learning cycle perfectly matches to nature of the topic [electrochemistry] and I choose to use 5E learning cycle" **(Stimulated recall interview)**

Defne thought that she knew the nature of the topic and general concepts of electrochemistry, so she matched the electrochemistry and 5E learning cycle. In addition to this, she stated that she was familiar to the 5E learning cycle other than alternative instructional strategies such as inquiry. Science teaching method course also lead pre-service teachers to use 5E learning cycle. Furthermore, as it was mentioned previous stage, her instructional strategy choice, 5E learning cycle, was in line with her goals for teaching science

When it was observed, as it was mentioned in the previous part, she could not use 5E learning cycle effectively. Due to Defne had better content knowledge on galvanic cell compared to electrolytic and concentration cell, when it was examined the content knowledge used during the 5E learning cycle method, whilst she used 5E learning cycle during the galvanic cell topic, she utilized lecturing preponderantly during concentration and electrolytic cells. However, she could not use 5E learning cycle effectively. Lack of content knowledge or lack of knowledge of instructional strategy might be reasons of this situation. For instance, in 5E learning cycle, second stage is exploration. The purpose of this stage is to give a change to learners investigate the explorable questions utilizing materials to learn scientific knowledge (Luera, Moyer & Everett, 2005) During Defne 's instruction she guided the demonstration related to galvanic cell herself, students just observed the demonstration. Defne tried to make students cognitively active via asking questions such as "What did you observe when the salt bridge was removed?"**(Field note)** Hence the exploration stage was directly related to just galvanic cell and Defne dominated this stage rather than giving an occasion to students gain actual experience.

On the other hand, Zeynep didn't choose a subject specific strategy for her instruction like Defne. She stated that she used discussion during her instruction but based on data taken from observations, her instruction could be labeled as teacher centered instruction enriched with analogy, animations, videos demonstrations and daily life application of the topics.

In her own words, she explained her instruction as:

> "..The nature of the topic is very appropriate to discussion. Due to the nature of topic, I could enrich the instruction with demonstration, videos, daily life applications, and animations including microscopic level. Also I could integrate NOS into electrochemistry so my main aim was not to give the content as lecturing, I would prefer to make them experience in practice in addition to pure content"

Similar with Defne, Zeynep emphasized the role of nature of the topic in her instruction strategy choice. Based on the observation data, Zeynep had adequate content knowledge on galvanic, concentration and electrolytic cell but she underlined the lack of teaching experience and classroom management skills prevent her from enactment instruction effectively. During the stimulated recall interview, she stated that "…after watching my instructions, I realized that I could not enact the instruction via discussion effectively. I generally give the answers just after the questions so the discussion environment cannot be created. Instead of this, I would try to understand why students respond the question in this way, what is the logic behind this or why lead them think like this." Hence, it can said that her subject matter knowledge was not the only factor but influenced pre-service teachers' method choice.

4.4.3.2 Content knowledge and topic specific instructional strategies interaction

Defne utilized her content knowledge in order to choose appropriate instructional strategies in order to make the content more understandable or to eliminate students' difficulties or misconceptions related to topic. However, in some excerpts during the instruction, while using instructional strategies Defne dominated the class and mostly she provided the explanation related to topic. For instance, while explaining the spontaneous and nonspontaneous reactions in terms of galvanic and electrolytic cell, she used a waterfall analogy.

She differentiated spontaneous and nonspontaneous reactions utilizing analogy as following during the instruction:

> **Defne:** most probably you see waterfall, so you know in waterfall there is a flow from top to bottom. Have you ever seen a waterfall, is there a flow from bottom to top?
> **Students:** No
> **Defne:** So in waterfall there is flow from high potential to low one and it is spontaneous as galvanic cell, for the reverse one, there is need for an external energy. If we apply external energy, waterfall may flow from bottom to top like electrolytic cell. It is nonspontaneous. **(Field note)**

After the instruction, she explained how she utilized her content knowledge in order to decide appropriate analogy as; "I learned spontaneous and nonspontaneous reactions from chemical reaction and energy topic so I wanted to use this analogy. Also this analogy was used to lead students understand and remember the concept easily" **(Stimulated recall interview)**

As it can be seen from the interview and field note, due to Defne's content knowledge, she prefer to use an analogy to make the concept more understandable and eliminate possible learners' difficulties.

Similar situation is valid for Zeynep while she was teaching concentration cell and electrolytic cell, she chose and used different kinds of representations appropriate to the sub-topic of electrochemistry utilizing her content knowledge. For instance, she explained how we determine anode and cathode electrode in concentration cells utilizing drawing of concentration cell (macroscopic representation) and writing half-reactions occurring anode and cathode (symbolic representations). Another example could be given from electrolytic cell, she preferred to use video and animation while explaining the electrolysis of water and NaCl solution. During the stimulated recall interview, she explained that: “I know that electrolysis is a bit complicated and abstract concept, but I think electrolysis is important and we used it in our daily life so I choose an appropriate animation for indicating electrolysis of water in microscopic level” **(Stimulated recall interview).** Zeynep’s content knowledge regarding the sub-topics of electrochemistry shaped her choice in terms of instructional strategy.

On the other hand, lack of content knowledge influenced pre-service teachers’ choices regarding topic specific instructional strategies. For instance, while explaining galvanic cell Defne preferred using animation and demonstration in addition to verbal explanation, however during the concentration cell she just preferred verbal explanation due to her lack of knowledge. The interview excerpt indicating this situation as following:

> **Researcher:** Do you know how to identify anode and cathode in concentration cell?
> **Defne:** the concentrated half-cell is cathode and the diluted half-cell is anode
> **R:** why? Do you know the reason?
> **D:** No I read from the textbook and I don’t know the underlying reason.
> **R:** during your instruction you just said that and moved on? Why did you ask anything to students related to this topic?
> **D:** I don’t have deep knowledge related to this subtopic so I don’t prefer to discuss with whole class.
> **R:** you utilized representations such animations, demonstrations while explaining galvanic cell but why do you prefer lecturing while explaining concentration cell?
> **D:** I think galvanic cell is the most important concept in this topic, the other cells, concentration and electrolytic cells are other formation of galvanic cell but the main process is same I mean oxidation and reduction reactions occur. In concentration cell the same process takes place, but the same electrodes are used but different concentration.
> **R:** could you evaluate your content knowledge in these subtopics?
> **D:** If I compare my content knowledge in terms of concentration cell and galvanic cell, I know less about the concentration cell.
> **R:** Do you think this affect your choice in terms of instructional strategy, I mean you prefer animation, demonstration etc. While explaining galvanic cell, but you prefer lecturing while explaining concentration cell?
> **D:** maybe, I gave just explanations. **(Stimulated recall interview)**

In this situation Defne's lack content knowledge tailored her instruction in terms of providing scientific explanation. She preferred to use lecturing to be in safe side rather student involved activities as discussion.

In Zeynep's case, although she generally had adequate content knowledge on electrochemistry, she had difficulty in determining the charges of electrodes so she ignored this and did not mention anyway. The reason of this was asked during the interview, she stated that

> "I know that the charges of electrodes are reverse in galvanic and electrolytic cells but I don't know why electrode charge is positive or negative or what the charges of electrodes in both cells is so I did not mention this during the instruction"

Another example from Defne's instruction, in the factors affecting cell potential, she just knew basic relation between the factors and cell potential, in other words she could not link conceptual relationships between different aspects of the content and grasp the underlying reasons of these relationships. For instance, regarding the effect of concentration change on cell potential, the reaction have a less tendency to occur when the concentration of product ion increased, a greater tendency to occur when the concentration of reactant ion is increased. In other words, if the concentration of reactant ion is increased, cell voltage will increase. During Defne's instruction she was supposed to make prediction related to effect of concentration change on cell potential without using Nerst equation, but she just explained it as a textbook statement via lecturing. Her lack of knowledge impacted her instruction. After the instruction, she was asked the reason of preferring to provide students scientific explanation rather than to discuss, she explained as:

> "I don't know the underlying reason of why concentration change effects the cell potential so I only say the sentence mentioned in the textbook as if we increase the concentration of ions in the anode half-cell, the cell potential will decrease" **(Stimulated recall interview)**

Moreover, during the instruction, she had difficulty in constructing explanations to the responses of learners' questions due to lack of her content knowledge. For instance, in electrolytic cell sub-topic, just after Defne explained galvanic cell and electrolytic cell have reverse reactions, students asked the function of battery in identifying electrodes as anode or cathode, but Defne could not understand the students' question so she made an inappropriate explanation as respond to question as "in electrolytic cell the value in voltmeter is negative but in galvanic cell it is positive. In electrolytic cell, an external energy is provided with battery" **(Field note).** During the stimulated recall interview, this section of the instruction was discussed and she stated that: "I think that we will identify anode and cathode in electrolytic cell by utilizing standard reduction potential table. But in electrolytic cell due to the battery, we think the reactions reverse."**(Stimulated recall interview)**

As it can be seen from the quotation, she did not know the function of battery in identifying anode and cathode in electrolytic cell. Because of the uncertainty in her content knowledge, she was inadequate to respond students' spontaneous question during instruction and her explanations were not directly related to the question. Table 19 indicated the summary of the result regarding the interaction between pre-service teachers' content knowledge and knowledge of instructional strategies.

Table 19. The interaction between knowledge of instructional strategy and content knowledge for teaching electrochemistry

	Defne's Knowledge of Instructional strategy		**Zeynep's Knowledge of Instructional strategy**	
	Subject specific instructional strategies	Topic specific instructional strategies	Subject specific instructional strategies	Topic specific instructional strategies
Content knowledge	Defne preferred to use 5E learning cycle due to the nature of topic and her orientation towards science teaching. Defne's content knowledge did not have a strong impact on her subject specific instructional strategy choice.	Defne utilized her content knowledge to choose appropriate activities and representations to make the concept more understandable especially galvanic cell sub-topic. Lack of her content knowledge on electrolytic and concentration, she preferred just verbal explanations while teaching these topics. Due to her lack of content knowledge she had difficulty in constructing explanations to the learners' questions.	Zeynep did not use a subject specific instructional strategy. She enacted a teacher centered instruction enriched with animation, demonstration, analogy and videos. Zeynep's adequate content knowledge did not impact directly her subject specific instructional strategy choice.	Zeynep chose and used different kinds of representations and activities appropriate to the all sub-topic of electrochemistry utilizing her content knowledge.

4.4.4 Content knowledge and Knowledge of curriculum instruction interaction

4.4.4.1 Content knowledge and Knowledge of goals and objectives interaction

Both Defne and Zeynep determined the objectives to be addressed during the instruction from the National high school chemistry curriculum and chemistry high school textbook. But in addition to the objectives stated in these sources, they added objectives as mentioned in their CoRe. Examples from objectives written in Defne's and Zeynep's CoRe as following:

> "Students should be able to understand nature of science by explaining history of battery (additional objective) (Defne)
> Students should be able to design galvanic cell experiment (Additional objective) (Defne)
> Students should be able to understand working principles of galvanic cell with its components (Objective 3.1, p. 65, NME 2012) (Zeynep) (Defne)
> Students should be able to construct a cell system (additional objective) (Zeynep)"

During the interview, Defne explained how she determined these objectives for her instruction as:

> "I did not copy all the objectives stated in the curriculum to my CoRe, I chose the objectives based on the content I attend to emphasize during my instruction and I added a few objectives that was not stated in the curriculum".

Similarly, Zeynep stated that

> "I know electrochemistry so while I was determining the objectives, I took into account the important concepts in electrochemistry that I thought a teacher should emphasize…exactly my content knowledge effected my preferences in terms of objectives to be addressed during the instruction"**(Interview)**

So content knowledge regarding the topic was influential to choose the objectives that pre-service chose but although their content knowledge level was different, both of them choose similar objectives so it can be said that their goals for teaching science had more effect on their objectives rather than their content knowledge level.

4.4.4.2 Content knowledge and curricular saliency interaction

Both of the pre-service teachers were aware of the curricular saliency, in other words they knew the sequence of the topics in electrochemistry and the topics before and after the electrochemistry. During the instruction, Defne made small alterations regarding the demonstrations conducted as making the demonstration related to spontaneity of redox reaction before the galvanic cell demonstration. She thought that if students understand the spontaneity of redox reactions, they can more easily understand galvanic cell working principles.

On the other hand, Zeynep followed the curricular saliency exactly presented at the chemistry high school textbook. Although Zeynep had adequate knowledge on electrochemistry, she did not attempt to change sequence of the demonstrations due to other factors. She explained the reason of it as:

> "I wanted to follow the sequence of topics as given in the textbook and my CoRe. I am afraid of failing to respond the questions that may come from the students or explain the concept exactly during the instruction so I didn't take a risk and follow the high school chemistry textbook closely" **(Stimulated recall interview).**

Hence the level of content knowledge of pre-service don't have remarkable effect on their knowledge of curriculum regarding curricular saliency, both of them followed the high school chemistry textbook closely.

4.4.4.3 Content knowledge and altering the curriculum interaction

When I examined the whole instruction, Defne followed the textbook closely except a few changes. For instance, in electrolytic cell, the electrolysis of water and molten sodium chloride (NaCl) contents were ignored during the instruction although they were presented at the chemistry textbook. Furthermore, she did not make algorithmic calculations pertained to quantitative aspect of electrolysis during her instruction although there was an objective related to this content as

> "Students should be able to make algorithmic calculation using moles of electron, current, time and moles of product" (Objective 3.6, p. 65)

During the interview, the reasons for ignoring these sub-topics were asked, Defne stated that due to her superficial knowledge in electrolytic cells, she mentioned that she did not feel confident in responding questions that may come from students related to content she knew less (**Stimulated recall interview**).

On the contrary to Defne, Zeynep covered most of the objectives presented in the curriculum. Hence having adequate content knowledge may lead pre-service teacher to cover the objectives provided through the curriculum and not ignore or alter them.

4.4.4.4 Content knowledge and vertical curriculum interaction

As it was mentioned under the knowledge of curriculum sub-title, Defne did not connect electrochemistry with the topics that was presented in previous year or in later years. So there was no empirical evidence regarding connection between her content knowledge and knowledge of vertical curriculum. On the other hand, Zeynep associated electrochemistry topic with the types of reaction topic presented at 9^{th} grade as explained in the previous part. Having adequate knowledge may have caused her to establish the link between these topics.

4.4.4.5 Content knowledge and horizontal curriculum interaction

Defne and Zeynep dominantly connected electrochemistry to the previous topic, chemical equilibrium. Although Defne mentioned chemical equilibrium in two points during her instruction, the link between these two topics was superficial not including conceptual understanding. For instance, during explaining the concentration change effect on cell potential and Nerst equation, she connected the topic with Le Chatelier's principle in chemical equilibrium. During her explanation, she utilized a chemical reaction and mentioned what textbook stated in the classroom as

> "If we increase the concentration of ion in the anode half-cell, the cell potential will decrease" **(Field note)**

She did not provide conceptual explanation or how we utilized chemical equilibrium to interpret the effect of concentration change on cell potential. After the instruction, during the interview, she stated that

> "I don't know the underlying reason also I could not understand exactly. I just declare to students what I found in the textbook… If I evaluate my instruction, I could not relate chemical equilibrium and electrochemistry, I may blend these two topics a bit more. This is because of my lack of content knowledge, but for the next instruction I will study more on these topics." **(Stimulated recall interview)**

Another example from Defne's instruction was also related to association between chemical equilibrium and electrochemistry. In galvanic cell sub-topic, she asked students that "Does cell have a definite time or does a cell work forever?" Students answered as "Cell will work until one of the electrodes finish or cell reaches equilibrium". Defne referred chemical equilibrium, but she could not link conceptually these two associated topic in the class. During the interview, Defne stated that "I know that chemical equilibrium and electrochemistry are related but I don't have deep understanding about these, I just know cell run down when positive and negative ions become equal but I don't know the reason of it " **(Stimulated recall interview)**

Because of her lack of content knowledge in terms of both chemical equilibrium and electrochemistry, she tended to make superficial explanations and could not lead learners to understand conceptually rather she made learners memorize. Hence lack of content knowledge impacted her knowledge of curriculum in terms of horizontal al curriculum.

On the other hand, Zeynep made similar connections with Defne but the quality of this link was different. For instance, while explaining concentration change on cell potential, she mentioned that Le Chatelier's principle can be used to predict the effect of concentration change on cell potential without using Nerst equation **(Field notes).** Due to having adequate knowledge regarding electrochemistry and chemical equilibrium, she could establish conceptual link between these topics. Furthermore, Zeynep utilized chemical equilibrium during the concentration cell sub-topic. She used her content knowledge in chemical equilibrium to determine anode and cathode in concentration cell and explained as

> "..concentration cell is composed of two half-cell including same electrodes differing only in concentrations so when the concentration of reactant in both half-cell are equal, concentration cell reaches equilibrium. In the less concentrated half-cell oxidation reaction occurs in order to increase the concentration so labeled as anode, in the more concentrated half-cell reduction reaction occurs to decrease the concentration and labeled as cathode" **(Stimulated recall interview)**

Hence, content knowledge tailor the quality of knowledge of curriculum regarding horizontal curriculum.

4.4.4.6 Content knowledge and connection to other disciplines

An example of not linking an interaction was observed when Defne was explaining the electrolytic cell. Defne had superficial knowledge regarding electrolytic cell and she could not connect the concepts related to this concept. For instance, she did not know how we determine the anode and cathode electrode in electrolytic cell. As it is known, in galvanic cell electron moves from negative terminal to the positive one. However, in electrolytic cell, the electrode that is connected to the negative terminal of the voltage source (battery) is cathode, the electrode that is connected to the positive terminal of the voltage source is anode. So electron moves from positive terminal to the negative terminal. Also in physics courses, it was learnt that electron flow is from positive terminal to negative terminal. Defne had inadequate knowledge in terms of the connection between physics and chemistry so she did not link the topic to physics to help learners remember and use the knowledge they learned in physics
Table 20 indicated the summary of the results pertained to the interaction between knowledge of curriculum and content knowledge while teaching electrochemistry.

Table 20. The interaction between knowledge of curriculum and content knowledge for teaching electrochemistry

		Knowledge of Curriculum					
		Knowledge on goals and purposes	**Vertical Relation**	**Horizontal relation**	**Altering the curriculum**	**Curricular saliency**	**Connection to other disciplines**
Content knowledge	**Defne**	Defne determines the goals and objectives using content knowledge but content knowledge level doesn't have strong effect on this sub-component.	Defne did not link electrochemistry with the topic from previous year or later years.	Defne mentioned chemical equilibrium during her instruction, the link between these two topics was superficial not including conceptual understanding.	Defne ignored the sub-topics that she had superficial knowledge as electrolytic cell, she did not mention the objectives related to this sub topic.	Aware of the curricular saliency and followed the high school chemistry textbook closely.	Defne could not link electrochemistry to physic while explaining how we determine anode and cathode in electrolytic cells due to lack of knowledge on both electrolytic cell and physics.
	Zeynep	Zeynep determines the important concepts and objectives using her electrochemistry content knowledge.	Zeynep linked electrochemistry with the topic presented in previous years (types of chemical reaction)	Zeynep had adequate knowledge regarding electrochemistry and chemical equilibrium, so she could establish conceptual link between these topics.	Zeynep covered all the objectives presented in the curriculum.	Aware of the curricular saliency and followed the high school chemistry textbook closely. Although Zeynep had adequate knowledge on electrochemistry, she did not attempt to change sequence of the topics.	Zeynep used the knowledge learnt in physics to determine anode and cathode in electrolytic cells.

4.4.5 Content Knowledge and Knowledge of Assessment interaction

4.4.5.1. CK & Knowledge of methods of assessment (how to assess)

As it was mentioned in the knowledge of assessment part, Defne and Zeynep used informal questioning and homework to assess students' understanding. The interaction between content knowledge and the pre-service teacher's choice to how to assess students' understanding was detected regarding the quality and level of the questions asked during the assessment. For instance, Defne preferred to use informal questioning both to assess electrolytic cell and galvanic cell however the level of questions differed. Although she tended to ask knowledge level question or refrained from asking questions in electrolytic and concentration cell sub-topics, she asked higher cognitive level questions in galvanic cell. For instance, Defne asked questions to identify students' understanding about salt bridge like "what is function of salt bridge in galvanic cell?" "If we remove salt bridge from the galvanic cell, will the cell continue to work?" "Why cell stopped working when we removed salt bridge?" "Do electrons flow through salt bridge?"**(Field notes)** These questions were aimed to move beyond the low level cognitive questions. On the other hand, Defne generally ignored to ask questions to assess students' understanding in electrolytic and concentration cell due to her lack of knowledge. She stated that "I could not use informal questioning so much in electrochemistry for the content that I don't know exactly [concentration and electrolytic cell], I hesitate asking questions because I don't know what I should say as response to students" **(Stimulated recall interview).** She thought that she had difficulty to ask follow up questions and responding students' questions. The level of content knowledge influenced Defne in terms of deciding how to assess students' understanding. Zeynep also used informal questioning during her instruction for all subtopics of electrochemistry namely galvanic, electrolytic and concentration cell but she sometimes had difficulty in asking follow-up questions to assess students' understanding.

During the interview, reason of this situation was asked and she mentioned:

> “I don’t have so much teaching experience so I don’t feel familiar with the real classroom environment, I feel anxiety regarding to fail to answer the questions of students’ correctly so when I take the correct respond to the question I moved on the next topic” **(Stimulated recall interview).**

For summative assessment, Zeynep preferred to use interesting and researchable question related to how man-made diamond was produced. Her content knowledge may have led her to assess students’ understanding questions aimed to push students search and use their knowledge to explain new situations. The level of content knowledge influence the quality of questions preferred to assess students’ understanding.

4.4.5.2 CK& Knowledge of dimensions of science learning to assess (What to assess)

Defne and Zeynep predominantly assessed students’ conceptual understanding during her instruction. An example indicating the interaction between content knowledge and what to assess could not be detected. Table 21indicated the results of interaction between content knowledge and knowledge of assessment for teaching electrochemistry.

Table 21. The interaction between knowledge of assessment and content knowledge for teaching electrochemistry

	Defne's knowledge of assessment		**Zeynep's knowledge of assessment**	
	How to assess	**What to assess**	**How to assess**	**What to assess**
Content knowledge	Defne used informal questioning and homework to assess students' understanding. The qualities of questions were differed based on her content knowledge on the sub-topics of electrochemistry. Defne tended to ask knowledge level question or refrained from asking questions in electrolytic and concentration cell sub-topics	Defne assessed predominantly conceptual understanding. Defne asked a few questions regarding NOS aspects.	Zeynep used informal questioning and homework to assess students' understanding. She asked questions regarding the all sub-topics of electrochemistry. Zeynep used a researchable question as a homework	Zeynep assessed predominantly conceptual understanding.

CHAPTER 5

CONCLUSION, DISCUSSION AND IMPLICATIONS

5.1 Conclusion

There have been assertions regarding firstly, the pre-service chemistry teachers' nature of PCK and then, the interaction between PCK and CK on electrochemistry topic.

Assertions regarding nature of pre-service chemistry teachers' PCK

- Pre-service teachers had multiple purposes and goals for teaching science and they concentrated on schooling goals for teaching science.
- Pre-service teachers were aware of possible misconceptions and difficulties that students may have parallel with their content knowledge level. Also, pre-service teachers were aware of the students' possible difficulties and misconceptions due to having self-experiences as a student and knowing the related literature on the topic.
- Pre-service teachers had limited knowledge of curriculum. They had difficulty in making vertical and horizontal relations, altering the curriculum and connecting the topic with other disciplines. The quality of knowledge of learner changed parallel with their content knowledge.
- Pre-service teachers perceived textbooks as a source of information, followed the textbooks closely and the textbook influenced their instructions strongly.
- Pre-service teachers were more focused on teaching rather than thinking about students.

- Pre-service teacher assessed learners' understanding on the topic, NOS and daily life application in the topic utilizing traditional assessment methods. However, they had difficulty in interpreting and considering students' ideas to plan their instruction.

Assertions regarding the interaction between pre-service chemistry teachers' PCK and CK

- Content knowledge and pedagogical content knowledge were correlated knowledge bases but they are separate and there is not direct proportion between them.
- Basic level of content knowledge is required for teaching in other words there is a threshold for transforming content knowledge into an understandable way for students.
- A basic level of CK is a prerequisite for developing PCK, while a high CK does not affect a high PCK to the same extent.
- The comparison of pre-service chemistry teachers teaching on electrochemistry who are with strong and weak content knowledge revealed that there have been remarkable differences in terms of PCK components.
- Pre-service teachers with having different content knowledge level preferred to use traditional assessment methods.
- The level of content knowledge tailored the quality of knowledge of curriculum regarding horizontal, vertical relation and connection between other disciplines.
- Pre-service teacher with high content knowledge was more aware of the possible misconceptions compared to one having low content knowledge.

5.2. Discussion

5.2.1. Discussion of the results of nature of PCK

5.2.1.1 Orientation to science teaching

In this study, both of the pre-service teachers' orientation to science teaching was teacher centered but their teaching orientation included central and peripheral goals. Friedrichsen and Dana (2005) mentioned that teachers' orientations have a complex nature and do not comprise of a central and single component of orientation. Hence, in this study teaching orientation of pre-service teachers' goals for teaching science were categorized as central and peripheral goals including subject matter, affective and schooling goals proposed by Friedrichsen & Dana (2005). In the current study, both of the pre-service teachers focused on schooling goals pertained to preparing students for applying science concepts to their daily life, promoting students' scientific literacy and preparing students for the university entrance exam. In addition to that, pre-service teachers held affective goals as leading students to develop positive attitude towards science. Hence, participants had multiple purposes for teaching science that is parallel with the literature (Demirdogen, 2016; Friedrichsen & Dana, 2005) During the instruction, in addition to schooling goals, participants had subject matter goals as central goals as providing conceptual understanding of chemistry concepts. When it was examined, there were small differences between interview and classroom observation in terms of participants' goals and purposes for teaching science on the contrary to the studies conducted with experienced teachers (Aydin, 2012; Şen, 2014). Due the courses that were taken by pre-service teachers during the teacher education program, the instructors usually underlined the importance of providing experiments and activities, associating the science concepts to the daily life application and using instructional strategies promoting students' meaningful understanding so pre-service teachers were more aware of these. Furthermore, because of the course requirement they were supposed to supply, they made an effort to apply them in their teaching.

Although pre-service teachers enriched their lecturing with analogies, demonstrations, animations and activities consistent with their goals and purposes for science teaching, they preferred to use lecturing mainly in other words they preferred to use teacher centered instruction. This finding was parallel with Friedrichsen, Abell, Pareja, Brown, Lankford and Volkmann (2009) and Brown, Friedrichsen and Abell, (2013). Brown et al. (2013) mentioned that pre-service teachers believed that science teaching can be supplied by transmitting the knowledge to students. The possible reason of this may be experiences as a student regarding learning science is teacher centered (Brown et al. 2013), lack of teaching experience in real classroom environment and inadequacies in their content knowledge.

5.2.1.2 Knowledge of Learner

In this study, pre-service teachers were knowledgeable regarding knowledge of learners' understanding on electrochemistry. In other words, they were aware of prerequisite knowledge required to learn electrochemistry, and possible difficulties and misconceptions that students may have related to the topic.

Although studies in the literature mentioned that pre-service teachers were not aware of the misconceptions related to the topic (Käpylä et al. 2009; Nakiboglu, Karakoc & De Jong, 2010; Usak et al. 2011), in this study pre-service teachers were generally aware of the misconceptions and difficulties congruent with their content knowledge level on electrochemistry. When pre-service teachers had adequate content knowledge on the topic, they had better understanding on students' misconceptions and difficulties. The sub-topics that they had inaccurate knowledge about, they were unable to identify students' misconceptions and difficulties. This is also consistent with other research studies (Halim & Meerah, 2002; Hashweh, 1987; Käpylä et al. 2009; Kaya, 2009). Käpylä et al. (2009) reported that pre-service teachers with weak content knowledge could not realize any learning difficulties that student may come across.

During the instruction, sometimes pre-service teachers missed the misconceptions that students had due to lack of their content knowledge. This finding was consistent with related literature (Sanders et al., 1993; Hashweh, 1987) Hasweh (1987) stated that unknowledgeable teachers were not aware of the possible misconceptions that students have due to having similar misconceptions with the students. Another reason may be explained due to the lack of teaching experience of pre-service teachers. As it was known teaching experience is the one of the most important factor for constructing PCK of teachers (van Driel et al., 2002). On the other hand, there have been studies indicating that teaching experience does not guarantee that teachers have rich PCK (Friedrichsen et al., 2009; Aydin, 2012) so the level of content knowledge has a crucial role on teachers' PCK. Hence having adequate content knowledge on the topic helped pre-service teachers to recognize students' misconceptions and learning difficulties during the instruction.

Furthermore, in this study, the source of pre-service chemistry teachers' knowledge on learners' difficulties and misconceptions was their own experience as a student and related literature on electrochemistry corresponding to the literature (Aydin et al. 2013) This is, however, contrary to the finding of Canbazoglu et al. (2010) stating that pre-service teachers were aware of the possible misconception and difficulties only due to their self-experiences rather than related literature. There have been several studies conducted to investigate common learners' difficulties and misconceptions in electrochemistry (Garnett & Treagust, 1992a, 1992b; Mutlu & Sesen, 2016; Ogude & Bradley, 1996; Ozkaya, 2002; Sanger & Greenbowe, 1997a, 1997b; Schmidt et al. 2007) and how to teach electrochemistry to improve students' understanding (Huddle et al., 2000; Yang, Andre & Greenbowe, 2003). During the courses taken at the teacher education programs, instructors underlined the importance of misconception and learning difficulties on students' learning and this may lead our pre-service teachers to take them into account during their instruction.

5.2.1.3 Knowledge of instructional strategy

In the study, surprisingly, while the pre-service teachers with low content knowledge preferred to use subject specific instructional strategy as 5E learning cycle, the other pre-service teacher having adequate content knowledge did not choose subject specific instructional strategy. Hence, the instructional strategy selection was not directly proportional to the level of pre-service teachers' content knowledge (Ingber, 2009;

Käpylä et al. 2009). It can be explained with the role of orientation on pre-service teachers' instructional decisions (Magnusson et al. 1999). Although there have been inadequacies in Defne's electrochemistry content knowledge, she chose 5E learning cycle due to her goals for teaching science. Another reason might be the effect of disciplinary education on pre-service teachers PCK (Grossman, 1990). During science methods course preservice teacher are getting used to preparing 5E learning cycle lesson plans on general chemistry topics and teaching this plan to their peers. So they were supposed to be familiar to 5E learning cycle instructional strategy and when they are supposed to make an instruction they prone to make an instructional decision in favor of 5E learning cycle. In the literature researchers investigating the factors affecting the instructional decisions of pre-service teachers (Aydin et al., 2010; Boz & Boz, 2008) stated that pre-service teachers' content knowledge as a factor that effect their instructional decisions but these studies proposed other factors in addition to content knowledge namely pedagogical knowledge, nature of topic, mentor, experiences as a student and as a teacher, belief and feelings have an effect on their instructional decisions.

During their instruction, pre-service teachers used representations as animations, figures and analogies. Regarding representations, three faces of chemistry which are macroscopic, symbolic and microscopic (Talanquer, 2011) were used by pre-service teachers for explaining different sub-topics of electrochemistry. It is crucial to make connections among three levels of representations to promote conceptual understanding of chemistry (Hinton & Nakhleh, 1999; Treagust, Chittleborough & Mamiala, 2003). Participants preferred to use symbolic, macroscopic and microscopic representations simultaneously to explain a sub-topic consistent with their content knowledge at this topic. Pre-service teachers having low content knowledge on electrolytic cells preferred to use just macroscopic and symbolic representations in her explanations. Similar to this finding, De Jong and Van Driel (2004) reported that teaching difficulties regarding how to use macro-micro representations can be explained by pre-service teachers' content knowledge. In addition to content knowledge, pre-service teacher with weak content knowledge may have difficulty in using all levels and integrating these levels into the instruction while teaching a specific topic, for this study electrochemistry. Various studies reported findings parallel with this (Tarkin, Kutucu, Ekiz, Tuysuz, Bektas, & Uzuntiryaki, 2011; Pozo, 2001). Hence, lack of content knowledge (Smith & Neale, 1989) and lack of general pedagogical knowledge can be associated with ineffective usage of topic specific instructional strategies (Magnusson et al. 1999)

Another point was that both pre-service teachers used analogy to make the concept more understandable for students but both of them had difficulty in using analogy effectively as ignoring to emphasize similarities and differences between target and analogue concepts. Pre-service teachers used analogies especially sea level analogy while explaining the standard hydrogen electrode concept considering their knowledge of students' possible misconceptions (De Jong, Veal & van Driel, 2002) De Jong et al. (2002) stated that teachers preferred to use analogies while explaining some parts of chemistry topics that students had learning difficulties.

Although pre-service chemistry teachers did not assess students' NOS understanding effectively, they mentioned NOS aspects explicitly and history of electrochemistry during their instruction in parallel with their goals for teaching science. They mentioned the historical evolution of galvanic cell process and highlighted the tentativeness aspect of NOS explicitly as suggested by the literature (Abd-El-Khalick & Lederman, 2000). They underlined the explicit approach :"... even though any attempt to foster better understandings of NoS among science teachers should be framed within the context of the content and activities of science, these attempts, nevertheless, should be explicit and reflective."(Abd-El-Khalick & Lederman, 2000, p. 691). In the national chemistry curriculum, there was no emphasis regarding NOS and NOS aspects but during science teaching methods course, pre-service teachers were provided a conceptual framework that helped them improve their understanding regarding NOS aspects and how to teach NOS in their instruction so pre-service teachers were attentive to integrate NOS aspects into their instructions. Hanuscin (2013) also underlined that pre-service teachers develop their knowledge on how to teach NOS in science methods course works.

5.2.1.4 Knowledge of curriculum

In this study, pre-service chemistry teachers had limited knowledge of curriculum. Pre-service teachers differentiated in terms of using and quality of knowledge of curriculum based on their content knowledge. For a pre-service teacher, having adequate content knowledge, her knowledge of curriculum and how to use that knowledge was better than the counterpart that having low content knowledge in terms of making vertical and horizontal relations, connecting the topic to the other disciplines, and altering the curriculum. This finding is consistent with the related literature (Canbazoglu et al. 2010; Kaya, 2009)

Although they were aware of most of the objectives presented in the national chemistry curriculum, they did not know how to use the curriculum effectively and also they did not have knowledge regarding limitations, warnings or other instructional recommendations presented at the national chemistry curriculum related to the topic (Friedrichsen et al. 2009).

In the current study pre-service teachers were aware of the sequence of the sub-topics but they were not able to change the sequence of the sub-topics. This may be related with content knowledge (Aydin, 2012) and lack of teaching experience in the real classroom environment. Having inadequacies in their content knowledge might prevent pre-service teachers making flexible changes if necessary during their instruction (Rollnick et al. 2008). Rollnick et al. (2008) mentioned that teachers' insufficient understanding regarding the topic might obstruct making the relation between concepts. Regarding teaching experience, as it was mentioned before, pre-service teachers could not find so much opportunity regarding teaching in a real classroom environment so they did not want to take risk and instead of changing the sequence of sub-topics in the electrochemistry they closely pursued the sequence of the topic presented in the high school chemistry textbook and accepted the textbook as a guide (Yore, 1991). Yore (1991) stated that science teachers usually seemed textbook as a source of information that shaped their teaching. Furthermore, pre-service could not differentiate national chemistry curriculum and chemistry textbook. When it was mentioned about curriculum, they generally perceived it as chemistry textbook. This point was consistent with the literature (Friedrichsen et al. 2009) as pre-service teacher equated national curriculum with the textbook. Hence, they closely pursued the activities and questions existing in the chemistry textbook.

When it was examined the national chemistry curriculum for the 11^{th} grade in Turkey, there have not been any goals regarding nature of science, but pre-service teachers determined goals pertained to nature of science in addition to the goals presented to the curriculum for their teaching. This may be associated with the given importance to NOS by teacher educators during courses at the teacher education program.

5.2.1.5 Knowledge of Assessment

Regarding knowledge of assessment, pre-service teachers implemented assessment method as informal questioning and homework in order to identify learners' prior knowledge, misconception and understanding pertained to electrochemistry.
Pre-service teachers were aware of the prior knowledge and misconceptions that students may have and the importance of students' views on the topic (Van Driel et al. 1998; 2002). As it was known, in order to learn electrochemistry effectively, students are supposed to know some main concepts namely chemical reactions, chemical equilibrium, redox reactions and so forth. Hence, they used informal questioning to identify learners' prior knowledge however, their questions were too vague and general (e.g. "what is electrochemistry?") so it seemed that their purpose for asking these questions was to attract students' attention and focus their prior knowledge to the instruction instead of considering learners' prior knowledge to tailor their instruction. This finding confirms with the existing literature (Friedrichsen et al., 2009; Meyer, Tabachnick, Hewson, Lemberger & Park, 1999). Meyer et al. (1999) underlined that pre-service teachers tried to diagnose students' understanding and prior knowledge but they rarely used this, instead they used this assessment for motivating students, and leading students to take responsibility regarding their own learning and being aware of what they know or do not know. One of the possible reasons of it might be that pre-service teachers focused themselves as teachers rather than students as learners in other words they focused on their instruction rather than noticing students'

learning and also pre-service teachers did not have adequate knowledge how to use students' prior knowledge to plan or shape their instruction (Tabachnick & Zeichner, 1999)

Pre-service teachers also utilized informal questioning to recognize students' possible misconception during their instruction in line with their knowledge of learner.
The studies focused on the interaction among PCK components concluded that knowledge of learner especially being aware of students' misconceptions tailored teachers' knowledge of assessment (Park & Oliver, 2008; Henze, van Driel & Verloop, 2008).

Another issue regarding the knowledge of assessment is knowledge of dimensions of science learning to assess. In the current study, pre-service teachers did not focus not only content that was supposed to learn by students but also students' NOS understanding and daily life applications of electrochemistry. This finding was in contrast to the previous research conducted with teachers (Hanuscin, Lee, & Akerson 2011, Aydin, 2012). During teacher education programs, teacher educators present explicit and reflective instructional strategies to pre-service teachers regarding NOS especially during science methods courses so they were aware of the importance of emphasizing nature of science explicitly and integrated the NOS aspects into the chemistry topic.

Another point is pre-service teachers' knowledge of assessment methods. Both of the pre-service teachers preferred very similar assessment strategies as informal questioning and homework. Alternative assessment strategies may also be used, but pre-service teachers preferred to use traditional ones. This may be due to having insufficient knowledge pertained to knowledge of assessment techniques and how to use them in practice (Bektas, Ekiz, Tuysuz, Kutucu, Tarkin, & Uzuntiryaki, 2013; Friedrichsen et al. 2009). In the literature, among PCK components, knowledge of assessment is generally one of the least developed or undeveloped (Hanuscin et al. 2011; Henze et al. 2008)

5.2.2. Discussion of the results of interaction between CK and PCK

5.2.2.1 Content knowledge and orientation to science teaching interaction

In the study, both of the pre-service teachers enacted teacher centered instruction as Geddis (1993) and Friedrichsen et al. (2009) reported similar findings that pre-service teachers view teaching as transferring information to students so their instruction generally teacher centered. Halim and Meerah (2002) explained this situation as pre-service teachers tend to focus on their teaching and “view teaching as telling and not representing content for pupils’ learning” (p. 223).

In terms of determining goals and purposes for science teaching, both pre-service teachers determined similar goals for science teaching although they have different level of content knowledge. It can be concluded that content knowledge had no strong impact on determining pre-service teachers’ goals and purposes for science teaching.

5.2.2.2 Content knowledge and knowledge of learner interaction

When it is examined, pre-service teachers emphasized students’ misconceptions regarding electrochemistry consistent with their content knowledge level on electrochemistry. Pre-service teacher with high content knowledge was more aware of the possible misconceptions compared to one having low content knowledge. For instance, the sub topics as concentration and electrolytic cells that her content knowledge was inadequate, she was less aware of students’ possible misconceptions as similar with findings of Hashweh (1987), Käpylä et al. 2009 and Halim and Meerah (2002). Halim and Meerah (2002) stated that when the teacher had more scientifically incorrect concept about the topic, they could identify students’ misconceptions less. Also, due to lack of content knowledge, pre-service teacher had difficulty to recognize student misconception most probably due to having the similar misconception (Käpylä et al. 2009; Nakiboglu et al., 2010; Hashweh, 1987; Van Drirel et al. 2002). Furthermore, pre-service teacher with low content knowledge could not interpret students’ question or explanations correctly and sometimes her judgements were not appropriate so this may have reinforced misconceptions for students. This finding was also reported by Halim and Meerah (2002). An interesting finding in this study was that lack of content knowledge of pre-service teacher triggered her to emphasize the misconceptions and difficulties during her instruction and offered analogies and animation to make the concept more understandable for students by looking at her past experiences as a learner. The pre-service teacher with having robust content knowledge sometimes could not think that students would have these misconceptions regarding this topic.

In terms of prior knowledge both of the preservice teachers were aware of the prior knowledge but they had difficulty in using this prior knowledge while planning and enacting their instruction (Tabachnick & Zeichner, 1999). Tabachnick & Zeichner (1999) also stated that although pre-service teachers able to elicit prior knowledge they were unable to use this information to plan their instruction.

5.2.2.3 Content knowledge and knowledge of instructional strategies interaction

In terms of choosing subject specific strategies, while pre-service teacher with low content knowledge chose to use 5E learning cycle, the pre-service teacher with high content knowledge chose traditional instructional strategy that was enriched with activities and representations. Hence, it can be concluded that having better content knowledge had no strong impact on pre-service teachers' knowledge choice on subject specific instructional strategies. This result stand in line with Käpylä et al. (2009) and Ingber (2009). One reason for chosen a more student-centered by a pre-service teacher with weak content knowledge might be conceal of the lack of content knowledge.

When pre-service teachers' instruction was examined, both of pre-service teachers used similar topic specific strategies such as animation, analogy, videos, demonstration and drawings during their instruction but they differentiated in terms of effective usage of them parallel with their content knowledge level. Having better content knowledge in a sub-topic led them to choose a more student-centered or teacher-centered approach. Participant with solid content knowledge tended to use discussion, while the other one with inadequate content knowledge was reluctant to use student centered approach due to probability of not being able to respond students' spontaneous questions. Regarding the topic specific activities, they don't have so much experience and knowledge which demonstration or experiment is more appropriate for their teaching, most of the activities and representations used in their teaching were taken from the chemistry textbook (Nakiboglu et al., 2010)

Based on the literature the teachers who is more familiar with the topic have a tendency to talk less and choose activities that involve students more, however the teachers who are less familiar with the topic are keen on more talking and prefer to use teacher centered activities (Sanders et al. 1993) In the current study, both of them gave opportunity the students involved the instruction in which subtopics they feel comfortable in terms of their content knowledge level.

5.2.2.4 Content knowledge and knowledge of curriculum interaction

In this study, level of content knowledge had impact on pre-service teachers' knowledge of altering the curriculum, vertical and horizontal relations, and connections to other disciplines. Pre-service teacher with less knowledge of content knowledge had superficial knowledge on vertical and horizontal relation, and link between other disciplines, and also she was not able to connect the other topic conceptually that were supposed to associate with teaching electrochemistry. In other words, lack of content knowledge prevented pre-service teachers to make connection between topics to improve students' understanding on electrochemistry. On the other hand, pre-service teacher who was more knowledge in content knowledge discussed the relation and tried to explain the connection conceptually.

Although both of the participants determined the objectives covering the whole topic, during the instruction they chose to teach the subtopics regarding their content level. The pre-service teacher with less content knowledge on concentration and electrolytic cells did not emphasize these topics during her instruction. Content knowledge level had an impact on pre-service teachers' decision on determining the most important topics during their teaching and pre-service teacher sometimes ignored some of the concepts during their instruction parallel with inadequacies their content knowledge. One of the reasons might be to try to conceal weaker content knowledge. This finding was consistent with other studies in the literature as Käpylä et al. (2009), Kaya (2009), Sanders et al. (1993) and Canbazoglu et al. (2010). Käpylä et al. (2009) stated that pre-service teachers with strong content knowledge emphasized most important concepts than their counterparts with weak content knowledge. Hashweh (1987) also stated that "Teachers planned to teach the concepts used in the textbook however, they were also important additions and deletions partly affected by the teachers' prior SMK. Teachers tended to delete details they themselves could not remember "(p. 115) Hence having adequate content knowledge may lead pre-service teacher to cover the objectives provided through the curriculum and not ignore or alter them.

On the other hand, concerning the goals and objectives in the curriculum, there was no remarkable difference between pre-service teachers with different content knowledge level. Both of them had general knowledge regarding the objectives presented in the national chemistry curriculum and did not have in depth knowledge on limitations, warning and suggestions proposed by the curriculum. In addition both of them mentioned additional objectives in their CoRe and their instruction pertained to daily life applications of electrochemistry, historical development of electrochemistry and nature of science also science process skill as making an experiment consistent with their goals for science teaching. This may be explained with the impact of courses in the teacher education programs. Grossman (1990) stated that disciplinary education is one of the important factors that contribute the construction of PCK. Hence, of course content knowledge was important to determine the objectives for teaching but the level of content knowledge did not have remarkable effect on determining the objectives. Most probably pre-service teachers' orientation to science teaching is more effective than content knowledge level on decisions of pre-service teachers regarding the objectives and goals.

5.2.2.5 Content knowledge and knowledge of assessment interaction

In this study, both of the pre-service teacher used traditional assessment method informal questioning for diagnostic and formative assessment and homework for the summative assessment. This finding is consistent with Kaya (2009) that found that pre-service teachers with having different content knowledge level preferred to use traditional assessment methods. This may be due to lack of knowledge regarding alternative assessment method and how to use them in practice. The level of content knowledge influence pre-service teachers decision how to assess students' understanding regarding the quality and level of the questions asked during their teaching. Although both of them used informal questioning for diagnostic and formative assessment during their teaching, they prefer to ask higher cognitive level questions in the topics in which their content knowledge is better. For instance, although Defne tended to ask knowledge level question or refrained from asking questions in electrolytic and concentration cell sub-topics, she asked higher cognitive level questions in galvanic cell. This finding consistent with Hashweh (1987) and Carlsen (1993). Both of these studies mentioned that while good content knowledge lead teachers to ask higher cognitive level questions, when teachers were unfamiliar to the topic they tended to ask low cognitive level questions that required recall information.

Although pre-service teachers mentioned daily life application of chemistry and nature of science in addition to conceptual knowledge on electrochemistry, they predominantly assessed students' conceptual understanding.

5.3. Implication

It can be derived from the results of the study and the points discussed, this study have various implications pertained to pre-service teacher education and teacher education researches.

Firstly, this study has implications for pre-service teacher education programs. Pre-service teacher education programs have crucial role on improving pre-service teachers', in other words future teachers', pedagogical content knowledge. During this program pre-service teachers need support in terms of teaching ability and content knowledge on chemistry topics. Lack of content knowledge is a kind of obstacle in pre-service teachers' PCK so specialized courses might be designed that link content knowledge and its impact on teaching practices in order to respond pre-service teachers' needs and concerns regarding CK and PCK. Although chemistry teacher education program have already courses related to almost each component of PCK namely "curriculum development and instruction in science education", "measurement and evaluation in science education" and "methods of science teaching I and II", these courses should be specialized integrating chemistry to this courses and propose much more opportunities to pre-service teachers to practice these gained knowledge in real classroom environment. For instance, the course related to measurement and evaluation can be modified to provide pre-service teachers both knowledge on alternative assessment methods and how to use them in practice. Moreover, engaging pre-service chemistry teachers on their own teaching of chemistry lead them make insightful shifts in their thinking about the instructions and views on how effective teaching might be so this initiate the development of PCK. Hence utilizing the power of reflection on professional development of pre-service teachers video stimulated recall interview might be integrated to practice teaching course.

For further research the relationship between content knowledge and pedagogical content knowledge need more research especially during the classroom teaching to examine how experienced teachers use their content knowledge in interaction with students, and how both CK and PCK interact. For pre-service teachers how content knowledge and pedagogical content knowledge develop during the classroom teaching and how content knowledge influence development of PCK and how PCK influence development of content knowledge might be investigated. Such kind of studies would contribute teacher educators understanding how teaching and content knowledge impact each other.

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APPENDIX A

CoRe (Content Representation)

<table>
<tr><td colspan="6">Name: Lesson Planning Form</td></tr>
<tr><td colspan="2">Chemistry Topic/Content Area:</td><td>Grade Level:</td><td colspan="3" rowspan="2">Curriculum Objectives to be Addressed:</td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td rowspan="2">1. What concepts/big ideas do you intend students to learn?</td><td>Concept and/or important idea #1</td><td>Concept and/or important idea #2</td><td>Concept and/or important idea #3</td><td>Concept and/or important idea #4</td><td>Concept and/or important idea #5</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2. What do you expect students to understand about this concept and be able to do as a result?</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3. Why is it important for students to learn this concept? (Rationale)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4. As a teacher, what should you know about this topic?</td><td colspan="5"></td></tr>
</table>

<table>
<tr><th colspan="2"></th><th>Concept and/or important idea #1</th><th>Concept and/or important idea #2</th><th>Concept and/or important idea #3</th><th>Concept and/or important idea #4</th><th>Concept and/or important idea #5</th></tr>
<tr><td colspan="2">5. What difficulties do students typically have about each concept/idea?</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">6. What misconceptions do students typically have about each concept/idea?</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">7. Which teaching strategy and what specific activities might be useful for helping students develop an understanding of the concept?</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">8. In what ways would you assess students' understanding or confusion about this concept?</td><td>Formative Assessment:</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Summative Evaluation:</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">9. What materials/ equipment are needed to teach the lesson?</td><td colspan="5"></td></tr>
</table>

APPENDIX B

İÇERİK GÖSTERİM MATERYALİNİN MÜLAKAT SORULARI

1. Pedagojik alan bilgisi al boyutlarından fen öğretimine karşı yönelimleri

a) Lisede kimya öğretiminin amacı nedir? Neden kimya öğretiyoruz? Öğrenciler açısından bahsettiğin bilgi beceri kazanımlara sahip olmak neden önemlidir?

b) CoRe da yazdığın amaçları/hedefleri(big idea) nasıl belirledin? Amaçları belirlemene neler yardımcı oldu?

c) Öğrenciler açısından bahsettiğin bilgi beceri kazanımlara sahip olmak neden önemlidir? Ornegin (CoRe 3. Madde) 1. Big idea galvanik pillerin çalışma prensibini öğrenmek neden önemli olduğunu düşünüyorsun? 3. Big idea da öğrencilerin günlük hayatta kullandığı pillerin özelliklerini öğrenmesinin önemli olduğunu ifade etmişsin. Bunları öğrenmesinin neden önemli olduğunu düşünüyorsun?

d) Elektrokimya alan bilginin bu amaçları belirlemende katkısı oldu mu? Evet ise nasıl?

e) Lisede elektrokimya konusunu öğretmenin amacı nedir? Neden elektrokimya konusunu öğretiyoruz?

f) Elektrokimya konusunu öğretirken öğretmen olarak rolün nedir? Bu rolü belirlemende elektrokimya alan bilginin katkısı var mı?

2. Pedagojik alan bilgisi al boyutlarından öğrenci anlama bilgisi

a) Öğrenciler elektrokimya konusunda önceden ne biliyor olabilir? Öğrencilerin elektrokimya konusunu öğrenebilmeleri için hangi ön bilgilere ve becerilere sahip olması gerekir? Buna nasıl karar verdin?

b) Öğrenciler bu kavramları öğrenirken ne tür zorluklarla karşılaşabilirler? Zorluk yaşamalarının sebepleri neler olabilir? Bunları nasıl öğrendin? Örneğin ders planında(içerik gösterim materyali) öğrencilerin yükseltgenme ve indirgenme kavramlarını anlamakta zorlanacaklarını düşünüyorsun. Anot ve katottun yüklerini tayin etmekte zorlanacaklarını ifade etmişsin. Ayrıca elektroliz sırasında iyonların göçünü anlamakta zorlanacaklarını yazmışsın. Bunları açıklayabilir misin?

c) İçerik gösterim materyalinde yazdığın zorluklara nasıl karar verdin? Açıklayabilir misin?

d) Öğrencilerin elektrokimya konusundaki ana kavramlarla ilgili olarak sahip oldukları yanlış kavramalar neler olabilir? Bu kavram yanılgılarının kaynakları neler olabilir? İçerik gösterim materyalinde yazdığın kavram yanılgılarına nasıl karar verdin?

e) Öğrencilerin elektrokimya konusundaki kavram yanılgıları ve yaşadıkları zorluklar sizin öğretiminizi etkiliyor mu? Nasıl? Dersinizi planlarken öğrencilerin zorlandıkları noktaları ve yanlış kavramalarını nasıl kullandın?

f) Elektrokimya konusundaki öğrencilerin sahip olabileceği olası yanlış kavramalar ve zorluklara sende sahip misin? Kendini elektrokimya alan bilgin açısından değerlendirir misin? Elektrokimya alan bilginin öğrencilerin sahip olacağı kavram yanılgıları ve zorlukları belirlemende etkisi var mı? Varsa nasıl?

g) Öğrencilerin elektrokimya konusundaki yanlış kavramalarını ve zorlandıkları noktaları nasıl öğrendiniz? Kaynaklarınız nelerdir? (kitap, kendi deneyimlerin vs.)

h) Senin sahip olduğun kavram yanılgıları veya zorluklar öğrencilerin kavram yanılgılarını ve zorluklarını belirlemede ne kadar etkili?

3. Pedagojik alan bilgisi alt boyutlarından Öğretim Strateji, Yöntem ve Teknik Bilgisi

a) Öğrencilerin bahsettiğin bilgi/beceri/kazanıma ulaşması için nasıl bir öğretim tasarlarsın? Bu derste kullanabileceğin öğretim stratejileri (analoji, gösteri deneyi, benzetim/simülasyon, grafik, günlük hayat vs.) neler olabilir?

b) İçerik gösterim materyalinde 5E öğrenme dongusu kullanmaya nasil karar verdin? Bu ogretim stratejisini seçmendeki temel sebep neydi? Bu stratejinin etkili olduğunu düşünüyor musun?

c) Ders planında engagement basamağında elektrokimyanın tarihçesinden bahsettin ve NOS vurgu yaptın. Neden bu basamakta bunu tercih ettin? Vb.

d) Yapmayı planladığınız bu aktivite/stratejinin etkili olacağını nasıl öğrendiniz?

e) Dersini planlarken hangi öğretim stratejisini kullanacağına karar vermende elektrokimya konusundaki alan bilginin katkısı nedir?

f) Bu strateji neden kimya öğretimi yapıyoruz sorusunda belirlediğin amaçlara ulaşmanda nasıl yardımcı oluyor?

g) Konuyu öğretirken öğrencilerin konu ile ilgili yanlış kavramalara sahip olduklarının farkında varırsanız ne yaparsanız?

4. .Pedagojik alan bilgisi alt boyutlarından Ölçme ve Değerlendirme bilgileri

a) Öğrencilerin planladığın dersin sonunda elektrokimya konusunda ne öğrendiklerini hangi ölçme tekniklerini kullanarak ölçersiniz? Neyi ölçmeyi amaçlıyorsunuz?

b) Ders planında biçimlendirici değerlendirme için soru-cevap yöntemini kullanıyorsun. Genel değerlendirme olarak T/F testi ve açık uçlu soru dağıtacağını söylemişsin. Niçin bu ölçme değerlendirme tekniklerini kullanmayı tercih ediyorsunuz?

c) Bu ölçme tekniklerini dersin hangi aşamasında kullanmayı tercih edersiniz? Niçin?

d) Öğrencilerin sahip oldukları önbilgileri değerlendirir misiniz? Neden?

e) Bu ölçme yöntemini seçmende elektrokimya konusundaki alan bilgin etkili oldu mu? Nasıl?

f) Yaptığın bu ölçme değerlendirme sana neyi anlatacak, öğrencilerin hakkında nasıl bilgiler sunacak?

g) Bu bilgileri derste veya dersini tasarlarken nasıl kullanırsın?

h) Bu şekilde ölçme değerlendirme yapmayı nasıl öğrendin?

5. Pedagojik Alan Bilgisi Alt Boyutlarından Müfredat Bilgisi

a) Kimya müfredatında elektrokimya konusunda belirlenen kazanımlar hakkında ne biliyorsun? Müfredatta bu konu ile ilgili öğrencilerin hangi kavram /becerileri geliştirmeleri beklenir? Bu kazanımları/becerileri uygun buluyor musun?

b) Müfredatta elektrokimya konusuna temel oluşturan konular nelerdir? Bu konunun temel oluşturduğu konular nelerdir? Yani bu konudan önce ve sonra gelen konular nelerdir?

c) Sizce öğrencilerin öğrenmesi gereken en önemli kavramlar/noktalar nelerdir? Bu noktaları/kavramları nasıl belirlediniz?

d) Öğrencilerin hangi kavramları öğrenmesini ve bu bilgilerle neleri yapabilmesini bekliyorsunuz?

e) Müfredatta elektrokimya konusunda bulunan kavramların sıralanışı nasıldır? Sen bu sıralamayı uygun buluyor musun? Neden? Yazarak gösterir misin?

f) Tasarladığın öğretimde herhangi bir kaynağa ihtiyaç duydun mu? Hangi kaynaklardan yararlanmayı tercih edersin?

g) Müfredatta elektrokimya konusu kimyanın diğer konularıyla ve diğer disiplinler (fizik vb) ile ilişkisi yapılmış mı? Bu ilişkilendirmeyi uygun buluyor musun? Neden?

h) Sen elektrokimya konusunu anlatırken kimyanın diğer konularıyla ve diğer disiplinler ile ilişkisini kurmuştun? Örnek verebilir misin?

i) Müfredatta elektrokimya konusu anlatılırken dikkat edilmesi noktalar sınırlıklar ile ilgili bilgi verilmiş mi? Uygun mu?

APPENDIX C

DERS ANLATIM SONRASI GÖRÜŞMELER İÇİN MÜLAKAT SORULARI

Ana Soru: Ders anlatımlarınız için amacınız/amaçlarınız neydi? Bu amacı/amaçları nasıl belirlediniz?

1. Elektrokimya üzerine yaptığınız öğretimi nasıl planladınız? Plan yaparken hangi noktalara odaklandınız/ağırlık verdiniz?
2. Bu şekilde plan yapmayı nasıl öğrendiniz? Kaynaklarınız nelerdir?

Öğretmen Adayının Ders Hakkındaki Görüşleri

1. Gözlemlediğim öğretiminiz ile ilgili ilginç kısımları seçtim. O kısımlar ile ilgili ders anlatım videolarınızı da izleyerek sorular sormak istiyorum.

1. ders saati ile baslarsak;

- Derse ilgi çekici bir resim ile başladın. Öğrencilere kurbağa ile pil arasında bir ilişki kurup kuramadıklarını sordun. Öğretim yaparken bu fotoğrafı kullanma nedeniniz nedir? O fotoğraf öğrencilerin konuyu öğrenmelerine nasıl yardımcı olabilir? Sence bu resmi etkili şekilde kullanabildin mi?
- Dersin yine başlarında elektrokimya konusunda pillerin tarihçesinden bahsediyorsun. Sence konunun tarihçesinin öğretilmesi ya da öğrenciler tarafından bilinmesi gerekli midir? Konunun tarihçesinden bahsetmenin nedeni nedir? Konunun tarihçesini bilmeleri öğrencilerin konuyu öğrenmelerine nasıl yardımcı olabilir?
- Elektrokimya hakkında verdiğin tarihsel bilgilerden sonra, öğrencilere sizce bilim adamları nasıl çalışıyor diye soruyorsun? Bilim kesin midir? Aslında bu soru ile birlikte derste bilimin doğasına vurgu yapıyorsun. Neden bilimin doğasına vurgu yapmayı tercih ettiniz? Bu sizin kimya öğretimi ile ilgili olan amaçlarınızı gerçekleştirmenize nasıl yardımcı olmaktadır?

- Teori nedir diye soruyorsun? Teori nedir kanun nedir? Öğrencilerden “teori ispatlanmamış kanun ispatlanmış” “hayır ikisi de ispatlanmış ama teori değişebilir, kanun değişmez.” Gibi cevaplar geliyor öğrenciler bu noktalarda neden zorlanmış olabilir?
- Teori kanun arasındaki ilişkiyi açıklarken Gaz yasalarından Charles yasasından ve kinetik teoriden örnek veriyorsun. Bilimin doğasını anlatırken neden kimya konusu ile entegre/bağlantı yaparak anlatmayı tercih ettin?
- Elektrokimya nedir? Bu soruyu neden sordun?
- Al ve Br_2 tepkimesini yazıp öğrenciye yükseltgenme indirgenme tepkimelerini yazdırıyorsun. Bu soruyu sormanın amacı neydi?
- Redox tepkimelerinin kendiliğinden gerçekleşip gerçekleşmeyeceği (Aktiflik) ile ilgili bir deney yapıyorsun. Bana biraz yaptığın deneyden bahsedebilir misin? Neden bu deneyi kullanmayı tercih ettin? Bu deney öğrencilerin konuyu öğrenmesine nasıl yardımcı olabilir? Bu strateji sizin kimya öğretimi ile ilgili olan amaçlarınızı gerçekleştirmenize nasıl yardımcı olmaktadır?
- Deney düzeneğini tahtaya çiziyorsun. O şemayı kullanma nedeniniz nedir? O şema öğrencilerin konuyu öğrenmelerine nasıl yardımcı olabilir?
- Elektrokimyasal hücrelerin iki çeşit olduğundan bahsediyorsun. Konunun başında elektrolit ve galvanik piller şeklinde ayrım yaparak anlatmayı neden tercih ettin?
- Sınıfta galvanik pil mekanizması ile deney yapıyorsun. Bana biraz deney düzeneğinden bahsedebilir misin? O deneyi kullanma nedeniniz nedir? Sınıfta yapılan deney öğrencilerin konuyu öğrenmelerine nasıl yardımcı olabilir?
- Deney düzeneğinde kullanılacak her bir elementi (elektrot, elektrolitik çözelti, tuz köprüsü, voltmetre) hepsini tanıtıyorsun. Neden bu şekilde bir anlatım tercih ettin?
- Tuz köprüsünde KCl tuzu kullanılıyor ve doygun çözeltisi olması gerekiyor diyorsun. Neden KCl tuzu kullanıldı? Tuz köprüsünde kullanılan tuzların özellikleri nelerdir? Neden doygun çözelti hazırlıyoruz?
- Deney düzeneği ile ilgili bir çalışma kâğıdı dağıttın. Bu çalışma kâğıdını dağıtmanın amacı nedir? Bu çalışma kâğıtlarını ders esnasında nasıl kullandın?

- Öğrencilerin galvanik pil ile ilgili anlamakta zorlanacağı ya da yanlış kavramaya sahip olabileceği noktalar nelerdir?
- Öğrencilere pil düzeneğinde anot katot hangisidir? Hangisinde yükseltgenme hangisinde indirgenme olacak diye soruyorsun? Bu soruları sormanın amacı nedir? Sence anot ve katot nasıl belirlenir? Öğrencilerden bu soruya nasıl bir cevap vermesini bekliyordun?
- Tuz köprüsü olmadan sistem çalışır mı diye soruyorsun? Öğrencilerden hayır çalışmaz diye cevap geliyor. Neden diye soruyorsun? Çok kısa süre çalışır diyor. Tekrar neden diye sorguluyorsun? Öğrenci pilin dönüşü olmuyor diyor. Sence öğrenci pilin dönüşü olmuyor derken ne düşünmüş olabilir? Öğrenciler tuz köprüsünün neden sistemde olduğunu açıklarken neden zorlanıyor olabilirler?
- Öğrencilere deney düzeneği üzerinden tuz köprüsünü sistemden çıkardığımızda voltmetrede okuduğumuz değeri gösteriyorsun. Öğrencilere düz anlatımla sıfır olacağını söylemek yerinde düzenek üzerinden anlatmayı neden tercih ettin?
- Öğrencilere tuz köprüsünün görevini tekrar soruyorsun? Öğrencilerden; "elektron akışını sağlar" "elektronları alıyor anottan katoda doğru yol/ köprü oluyor." "fazla iyonları tutuyor" "yük denkliğini sağlıyor." Öğrenciler bu cevapları verirken ne düşünmüş olabilirler? Örneğin elektron akışının sistemde nasıl olduğunu neden anlamakta zorluk çekiyor olabilirler?
- Deney mekanizmasındaki galvanik pil düzeneğini animasyon kullanarak tekrar anlattin. Neden animasyon kullanmayi tercih ettin? Kullanilan animasyon öğrencilerin konuyu öğrenmelerine nasıl yardımcı olabilir?
- Animasyonda ozellikle tanecikli yapiya vurgu yaptın. Tanecikli yapiya vurgu yapmanizin nedeni nedir? Tanecikli yapida anlatim yapmak öğrencilerin konuyu anlamasinda nasil yardimci olabilir?
- Tuz köprüsündeki iyonların dağılımından bahsederken kimyasal dengeye refer ediyorsun? Nedenini açıklayabilir misin? Kimyasal denge konusu elektrokimya konusunu anlamasinda rolü nedir?
- Bu derste kullandığın aktivitelere bakarsak ilk önce aktiflik ile ilgili bir deney yapıp daha sonra galvanik pil ile ilgili bir deney yapıyorsun. Deneyleri bu şekilde sıralamanın nedeni nedir?

- Dersin sonunda tuz köprüsünün görevini anlatarak iyonların dağılımını tahtada gösterdin. Ancak öğrencilerden tuz köprüsünden elektron akışı olduğunu düşünenler vardı onunla ilgili bir açıklama neden yapmadın?

APPENDIX D

Name-Surname:

ELECTROCHEMISTRY CONTENT TEST

1. Please state whether the explanations below are true or false by writing **"T"** for true and **"F"** for false.

a) ___ Standard reduction potentials can be measured independently without the use of other half- cell reactions with the known potentials.

b) ___ In electrolytic cell, inert electrodes are non-reactive towards oxidation and reduction.

c) ___ The fact that the E° for H_2 (1 atm)/H^+ (1 M) is zero is somehow based on the chemistry of H^+ and H_2.

d) ___ Anodes, like anions, are always negatively charged; cathodes, like cations, are always positively charged.

e) ___ In electrolytic cell with identical electrodes connected to the battery, the same reactions will occur at both electrodes.

f) ___ Working principle of concentration cells is based on the concentration difference of electrolytes in anode and cathode half-cells.

g) ___ In a galvanic cell, anode is always on the left and cathode is always on the right.

h) ___Electron can flow through the aqueous solution without assistance from the ions.

i) ___ Iron rusts when it contacts with both oxygen and water.

2. Which of the equations represent redox reactions? Please show your work and indicate what is oxidized, what is reduced.

1 $H_{2(g)} + Cl_{2(g)} \rightarrow 2\ HCl_{(g)}$

2 $SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(aq)}$

3 $NH_{3\ (aq)} + H_2O_{(l)} \rightarrow NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

4 $NH_{3\ (g)} + \frac{1}{2}\ O_{2\ (g)} \rightarrow 2\ NO_{2(g)} + 3\ H_2O_{(g)}$

3. Please balance the following redox reaction using **half-reaction method** and show your work step by step.

$$FeCl_{3(aq)} + SnCl_{2(aq)} \rightarrow FeCl_{2(aq)} + SnCl_{4(aq)}$$

4.

$$Ni^{2+}_{(aq)} + Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + Ni_{(s)}$$
$$Ca^{2+}_{(aq)} + Zn_{(s)} \rightarrow \text{no reaction}$$
$$Fe^{2+}_{(aq)} + Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + Fe_{(s)}$$

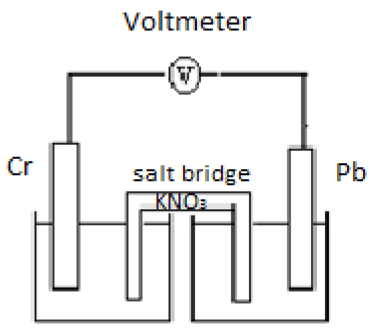
Answer the following questions according to the equations above:

a) Which substance undergoes oxidation and which undergoes reduction? Please show your work on each equation.

b) Which substance serve as the reducing agent and which as the oxidizing agent? Please show your work on each equation.

c) Rank the elements (Fe, Ni, Ca, Zn) from the strongest to the weakest in order of their reducing ability in aqueous solution.

5. Please answer the following questions according to electrochemical cell drawn below.



1.0 M $Cr(NO_3)_{3(aq)}$ 1.0M $Pb(NO_3)_{2(aq)}$

The salt bridge contains $KNO_{3(aq)}$

$Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$, E^o= -0.74V

$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$, E^o= -0.13V

a) Which electrode is the anode and which is the cathode? How would you determine which electrode is anode and which electrode is cathode? Please explain.

b) Please write half- reactions occurring at anode and cathode, and overall cell reaction.

c) What is the function of voltmeter?

d) What is the charge of anode and cathode in this cell? How would you determine the charges of each electrode? Please explain.

e) What is the direction of electron flow in this cell? Please draw the route of electron flow on the cell above.

f) In which directions do the cations and anions flow through the solution? Please draw the flow of ions at anode and cathode half-cells using arrows.

g) When galvanic cell operates, does any change occur in mass of each electrode with time? Please explain.

h) In which direction do anions and cations in the salt bridge ($KNO_{3(aq)}$) flow? Please draw the flow of ions using arrows.

i) What is the function of the salt bridge in this cell? Explain.

j) What would the value on the voltmeter be if the salt bridge were removed? (Increase, decrease, or no change). Please explain your answer.

k) Please write shorthand notation of the cell.

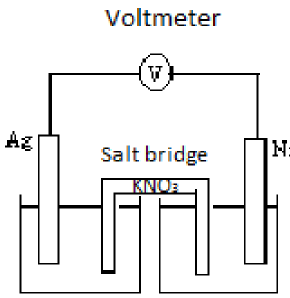
6. Answer the following questions related to standard hydrogen electrode.

a) What is a standard hydrogen electrode? Explain its importance.

b) Why does the reaction $2H^+ + 2e^- \rightarrow H_{2\,(g)}$ have an E° value of 0.00 V?

7. Why do batteries go dead?

8. Please answer the following questions according to electrochemical cell drawn below.



1.0 M $AgNO_{3(aq)}$ 1.0 M $Ni(NO_3)_{2(aq)}$

The salt bridge contains $KNO_{3(aq)}$

$Ag^+(aq) + e^- \rightarrow Ag(s)$, E°= +0.80V

$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$, E°= -0.25V

a) What is the cell potential of this cell? Please show your work.

b) What is the overall reaction for this cell? Does the redox reaction taking place in this cell occur spontaneous or nonspontaneous? How would you decide this? Please explain your answer.

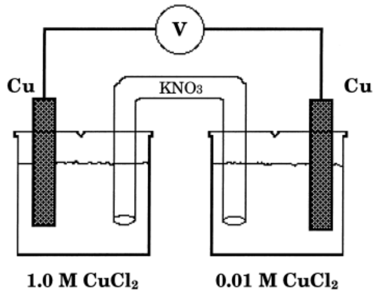
c) If the concentration of $AgNO_{3(aq)}$ was changed from 1.0 M to 0.1 M and concentration of $Ni(NO_3)_{2(aq)}$ remained at 1.0M, how the value of E_{cell} would be affected? (Increase, decrease or no change) Please explain your answer.

9. The cell potential produced in the reaction $Zn_{(s)} + Cu^{2+} \rightarrow Zn^{2+} + Cu_{(s)}$ is **dependent** of ________.

Please fill in the blank using the alternatives below. You can choose more than one alternative.

I. The size of the cathode
II. The metal used for the anode
III. The temperature
IV. The concentration of the Cu^{2+} ions

10. Please answer the following questions according to electrochemical cell drawn below



a) How would you decide which electrode is the anode and which is the cathode?

b) Could you please write the chemical reactions occurring at each electrode and overall cell reaction?

c) If the concentration in the right cell was changed from 0.01 M $CuCl_2$ to 0.001 M $CuCl_2$, What would happen to E_{cell} ? (Increase, decrease, no change, etc.)

d) When does this electrochemical cell stop working? Please explain your answer.

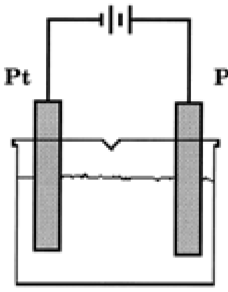
11. An electrolytic cell is used to produce molten aluminum from molten aluminum oxide, as represented by the simplified equation below.

$$2\ Al_2O_{3\,(l)} \rightarrow 4\ Al_{(l)} + 3O_{2\,(g)}$$

a) What are the half-reactions when molten aluminum oxide undergoes electrolysis?

b) If 50.000 A were applied to the electrolytic cell for 5 hours, then what is the mass of aluminum produced would be? (Al: 27 g/mole). Please show your work.

12. Answer the following questions according to the cell drawn below:



1.0 M $AlBr_{3(aq)}$

Standard reduction potentials:

$Al^{3+}_{(aq)} + 3e^- \rightarrow Al_{(s)}$	E° = -1,66
$2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$	E° = -0,83
$Br_{2(l)} + 2e^- \rightarrow 2Br^-_{(aq)}$	E°= 1,09
$O_{2(g)} + 4H^+_{(aq)} + 4e^- \rightarrow 2H_2O_{(l)}$	E° = 1,23

a) Is the cell a galvanic or an electrolytic cell? Explain why.

b) How would you determine which electrode is the anode and which is the cathode?

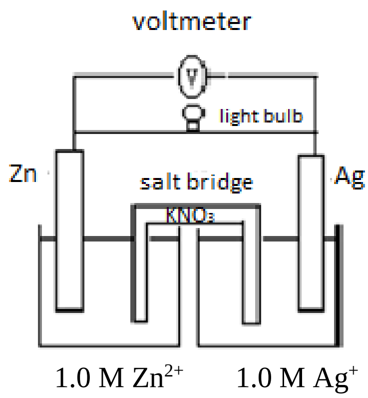
c) In which direction do **electrons** and **the charges (positive and negative ions)** flow in this cell to complete the circuit? Please use arrows.

d) What reactions are taking place at each electrode?

e) Does this redox reaction occur spontaneous or nonspontaneous? Can you predict the E value for this set-up?

f) Suppose the solution was changed to molten $AlBr_3$ — what reactions are taking place at anode and cathode?

13. Cars in coastal cities are more prone to rust. Why? Please provide a detailed explanation for your answer.



14. Evaluate whether the following claim and reason are **Correct** or **Incorrect**. Then please provide a detailed explanation for the answer you have chosen.

Claim	*Reason*
If the salt bridge in the picture above was replaced by a copper wire (an electrical conductor), the light bulb would be lit.	There will be a continuous flow of electrons in the electrolyte solutions that can pass through the copper bridge

Claim is correct / incorrect because………..

Reason is correct / incorrect because…………

15. Think that you are a chemistry teacher. While you are teaching electrochemistry one of your students, Ahmet, claimed "In the electrochemical cell, electron enter the solution from the cathode, travel through the solution and the salt bridge, and emerge at the anode to complete the circuit."

a) Do you agree with Ahmet? Please provide a detailed explanation for your answer.

b) If you think Ahmet's claim is not true, please provide a correct explanation.

You can use the following equations, in case of you need them to answer the questions.

$Q = I \times t$
$\Delta G° = -nFE°$ *(Standard free-energy change)*
$\Delta G = -nFE$ *(Gibbs free-energy change)*
$E_c = E_c^{\circ} - \frac{0,0592}{n} \times logQ$ *(Nernst Equation)*
1Faraday (F): 1F= 96485 Coulomb/mole

Thank you so much ☺

APPENDIX E

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
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07.05.2014

Gönderilen : Doç. Dr. Yezdan BOZ
Ortaöğretim Fen ve Matematik Alanları Eğitimi

Gönderen : Prof. Dr. Canan Özgen
IAK Başkanı

İlgi : Etik Onayı

Danışmanlığını yapmış olduğunuz Ortaöğretim Fen ve Matematik Alanları Eğitimi Bölümü öğrencisi Elif Selcan Kutucu'nun "Investigating the Interaction Between Pre-service Chemistry Teachers' Content Knowledge and Pedagogical Content Knowledge in Electrochemistry (Kimya Öğretmen Adaylarının Elektrokimya Konusundaki Konu Alan Bilgileri ve Pedagojik Alan Bilgileri Arasındaki İlişkinin Araştırılması)" isimli araştırması "İnsan Araştırmaları Komitesi" tarafından uygun görülerek gerekli onay verilmiştir.

Bilgilerinize saygılarımla sunarım.

Etik Komite Onayı

Uygundur

07/05/2014

Prof.Dr. Canan Özgen
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CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: KUTUCU, Elif Selcan

Nationality: Turkish (TC)

Date and Place of Birth: 15 April 1984, Ankara

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EDUCATION:

Degree	Institution	Year of Graduation
MS	Gazi University, Secondary Science and Mathematics Education	2007
BS	Gazi University Secondary Science and Mathematics Education	2007
High School	Suleyman Demirel Anatolian High School, Ankara	2002

PUBLICATIONS

A. Papers published in journals:

Aydin, S., Demirdogen, B., Tarkin, A., Kutucu, S., Ekiz, B., Akın, F. N., Tuysuz, M., Uzuntirkayi, E. (2013). Providing a set of research-based practices to support preservice teachers' long-term professional development as learners of science teaching. Science Education, 97(6), 903-935. DOI: 10.1002/sce.21080.

Bektas, O., Ekiz, B., Tuysuz, M., Kutucu, E. S., Tarkin, A. & Uzuntiryaki-Kondakci, E. (2013). Pre-service chemistry teachers' pedagogical content knowledge of the nature of science in the particle nature of matter. Chemical Education Research and Practice, 14, 201-213. DOI: 10.1039/C3RP20177E

Kirbulut, Z. D., Boz, Y. & Kutucu, E. S. (2012). Pre-service Chemistry Teachers' Expectations and Experiences in the School Experience Course. Australian Journal of Teacher Education, 37(2), 41-57.

Kutucu, E. S., & Ekiz, B. (2011). Pre-Service Chemistry Teachers Attitudes and Concerns towards Teaching Profession. E-journal of New World Sciences Academy Education Sciences, 1C0328, 6*(1),* 736-743.

B. Papers presented in International Conferences:

Kutucu, E. S., Ekiz, B. & Boz, Y. (2015). *Assessing Pre-Service Chemistry Teachers' Perceptions of Mentors' Pedagogical Content Knowledge through School Experience Course.* Paper presented at ECER 2015, Budapest, HUNGARY.

Ekiz, B., Kutucu, E. S., Luft, J. A., & Ozel, M. (2013). A Five Year Study of Beginning Secondary Science Teachers' Conceptualization and Enactment of Inquiry Based Instruction. Paper presented at ESERA 2013, Nicosia, CYPRUS.

Tarkin, A., Demirdögen, B., Aydin, S., Ekiz, B., Kutucu, E. S., Akin, F. N., Tüysuz, M. Uzuntiryaki, E. (2013). Providing meaningful experience to pre-service teachers: Mentoring enriched PCK based practicum course. Paper presented at NARST 2013, Puerto Rico, USA.

Ekiz, B.,Tuysuz, M. Bektas. O., Tarkin, A., Kutucu, E. S., & Uzuntiryaki, E. (2012). How Do Pre-Service Chemistry Teachers Connect Solubility of Gases in Liquids to Daily Life Events?. Paper presented at ECRICE 2012, Rome, ITALY.

Kutucu, E. S., Tarkin, A., Bektas, O. Ekiz, B., Tuysuz, M. & Uzuntiryaki, E. (2011). Pre-service Chemistry Teachers' Pedagogical Content Knowledge for Nature of Science on Matter. Paper presented at ESERA 2011, Lyon, FRANCE.

Ekiz, B.,Kutucu, E. S., Akkus, H. & Boz, Y. (2011). Pre-Service Chemistry Teachers' Understandings of Electrolytic Cells. Paper presented at ESERA 2011, Lyon, FRANCE. (Fulltext was published in proceedings of ESERA 2011)

Kutucu, E. S., Ekiz, B., & Akkus, H. (2011) Pre-service Science and Mathematics Teachers' Risk perceptions and Attitudes Towards Environment. Paper presented at ECER 2011, Berlin, GERMANY.

Ekiz, B., Kutucu, E. S., Tuysuz, M., Uzuntiryaki, E., Tarkin, A., & Kutucu, E. S. (2011). Pre-Service Chemistry Teachers' Understanding of Ionization and Dissolution. Paper presented at the 3rd World Conference on Educational Sciences 2011, İstanbul, TURKEY.

Tuysuz, M., Ekiz, B., Bektas, O., Uzuntiryaki, E., Kutucu, E. S. & Tarkin, A.(2011) Pre-Service Chemistry Teachers' Understanding of Phase Changes and Dissolution at Macroscopic, Symbolic, and Microscopic Levels. Paper presented at the 3rd World Conference on Educational Sciences 2011, İstanbul, TURKEY.

Kutucu, E. S., Ekiz, B., & Akkus, H. (2010) Assessing Pre-Service Science and Mathematics Teachers Environmental Literacy in Turkey. Paper presented in the 14th IOSTE 2010, Bled, SLOVENIA (Extended abstract was published in proceedings of IOSTE 2010).

Ekiz,B., Kutucu, E. S., & Akkus, H. (2010) Environmental Literacy of Pre-Service Science and Mathematics Teachers in Turkey: Effect of Gender and Academic Major. Paper presented in the 14th IOSTE 2010, Bled, SLOVENIA. (Extended abstract was published in proceedings of IOSTE 2010).

C. Papers presented in national conferences:

Ekiz Kiran, B., Kutucu, E. S., Kilinc, S., Soysal, C. & Boz,Y. (2016) Pre-service chemistry teachers' level of explaining daily life events utilizing their chemistry content knowledge. Paper presented in the 12th National Science and Mathematics Education Conference September 2016, Trabzon, TURKEY.

Tüysüz, M., Tarkın, A., Kutucu, E. S., Ekiz, B., & Bektas, O. Pre-service Chemistry Teachers' Mental Models on Factors Affecting Chemical Equilibrium. Mustafa, Ayşegül, Paper presented in the 11th National Science and Mathematics Education Conference September 2014, Adana, TURKEY.

Tüysüz, M., Tarkın, A., Kutucu, E. S., Ekiz, B., Aydın, S., Demirdögen, B. & Uzuntiryaki, E. (2012). Pre-service Chemistry Teachers' Views on Problems in Chemistry Education and Solution Suggestions. Paper presented in the 10th National Science and Mathematics Education Conference June 2012, Niğde, TURKEY.

Kutucu, E. S. & Ekiz, B. (2010) Pre-Service Chemistry Teachers Attitudes and Concerns towards Teaching Profession. Paper presented at 19th Educational Science Conference, September 2010, Lefkosia, CYPRUS.

Ekiz, B., Kutucu, E. S., Akkus, H. & Boz, Y. (2010) Pre-service Chemistry Teachers' Conceptions Concerning Salt Bridge. Paper presented in the 9th National Science and Mathematics Education Conference, August 2010, İzmir, TURKEY (Full text will be published in proceedings of 9th National Science and Mathematics Education Conference 2010, in press).

Kutucu, E. S., Ekiz, B., Boz, Y. & Akkus, H. (2010). Assessing Pre-service Chemistry Teachers' Understanding of Knowledge of Learner in the Context of Galvanic Cells. Paper presented in the 9th National Science and Mathematics Education Conference August 2010, İzmir, TURKEY.

Kutucu, E. S., Ekiz, B. & Boz, Y. (2009). Pre-service Chemistry Teachers' Level of Associating Chemistry Concepts to Daily Life Situations. Paper presented at 18th Educational Science Conference, 2009, İzmir, TURKEY.

D. Posters presented in conferences:

Tuysuz, M., Bektas, O., Tarkin, A., Kutucu, E. S., Ekiz, B. & Uzuntiryaki, E. (2012) Pre-Service Chemistry Teachers' Instructional Designs of 5E Learning Cycle Model on Intermolecular Forces. Poster presented at ECRICE, 2012, Rome, ITALY.

Tarkin, A., Kutucu, E. S., Ekiz, B., Tuysuz, M., Bektas,O. & Uzuntiryaki, E. (2011). Views on Teaching of Particulate Nature of Matter at Macroscopic, Symbolic, and Microscopic Levels. Poster presented at ESERA, 2011, Lyon, FRANCE. (Fulltext was published in proceedings of ESERA 2011)